Vol. XX. No. 6 PSYCHOLOGICAL REVIEW PUBLICATIONS November, 1913

THE

Psychological Review

EDITED BY

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HOWARD C. WARREN, Princeton University (*Index*)

JAMES R. ANGELL, University of Chicago (*Monographs*) and

ARTHUR H. PIERCE, Smith College (*Bulletin*)

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PUBLISHED BI-MONTHLY BY

PSYCHOLOGICAL REVIEW COMPANY

41 NORTH QUEEN ST., LANCASTER, PA.

AND PRINCETON, N. J.

Entered as second-class matter July 23, 1897, at the post-office at Lancaster, Pa., under Act of Congress of March 3, 1879.

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VOLUME XX, 1913

PUBLISHED BI-MONTHLY BY

PSYCHOLOGICAL REVIEW COMPANY

41 NORTH QUEEN ST., LANCASTER, PA.

AND PRINCETON, N. J.

Entered as second-class matter July 13, 1897, at the post-office at Lancaster, Pa., under Act of Congress of March 3, 1879.

PRESS OF
THE NEW ERA PRINTING COMPANY
LANCASTER, PA

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THE PSYCHOLOGICAL REVIEW

THE EFFECT ON FOVEAL VISION OF BRIGHT SURROUNDINGS

BY PERCY W. COBB AND L. R. GEISSLER

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In a previous paper one of the writers treated the question of a light source in the visual field and its influence on the vision of fine detail at the fovea. The present work has to do with the effect of extended bright area in the visual field on foveal vision as measured (*a*) by the smallest visible detail and (*b*) by the just-noticeable brightness difference.

These two criteria and their fluctuations with varying absolute brightness have themselves been the subject of extensive investigation by previous observers without especial reference to the background upon which the test field was seen.

The stimulus for any given small area of the retina might be quantitatively expressed as the illumination on that area, that is, as the amount of light per unit area falling upon that area. The response due to that area, as expressed in visual sensation, depends upon the stimulus at that point and upon other conditions, notable among which are the previous stimulation of the retina and the simultaneous stimulation of its other parts. These considerations have had abundant treatment under such heads as adaptation, after-image, successive and simultaneous contrast and induction.

Again, the stimulus at any part of the retina is not alone dependent upon the brightness at the corresponding part of its visual field, but also upon light entering the eye from

other parts of the field, a part of which is scattered within the eyeball instead of going to make the geometrical image.

These considerations all enter into the question of the influence on vision of light sources or bright surfaces within the visual field, an influence which has a very definite bearing wherever the limit of sensibility of the eye is under investigation.

Historical

The most extended set of data available on the variation of visual acuity with illumination (and color) is that of Koenig (1). In Koenig's work an opaque test object was used, illuminated from the same side as the observer, and the distance of the observer from the test-object was varied as well as the size of the test-object for different degrees of visual acuity. The result of such an arrangement is that the visual field surrounding the test-object has upon it an illumination varying in a rough way with the illumination upon the test-object, but with a very different distribution for different distances of the lamp. Further, the contents of the observer's visual field are altered in different cases by his own shifts in position toward or away from the test-object.

The variations of differential-sensibility of the eye at various absolute intensities have been exhaustively investigated by Koenig and Brodhun (2). In their work the field, of which the two halves were to be compared, was viewed through a small telescope, so that the test-field was seen on a background of physical darkness. The observer himself was closed in by black curtains so that the condition of his eyes approached that of dark adaptation except for the presence of the test-field.

As far, then, as concerns the influence on foveal vision of conditions in surrounding parts of the visual field the two sets of observations just cited tell absolutely nothing. In considering the results obtained it is imperative that the conditions as to the rest of the visual field, apart from the test-field, be also taken into account. The fact that a field kept at the same physical brightness may be made to look

white, gray, or black by exhibiting it on suitably chosen backgrounds is enough to raise grave suspicions as to whether the perception of detail and of brightness-differences would not be varied in some corresponding sense by the same treatment.

The literature of this question is meager. Some work has been done on the effect of a light source in the field of vision upon foveal vision for detail. This has been elsewhere cited (3). As to the effect of extended bright areas in the visual field, the writers have found only one piece of work in which the question has been quantitatively treated.

Hess and Pretori (4) conducted an investigation of the influence on the apparent brightness of a spot exerted by a surrounding field. It was found that the physical brightness of the spot had to be increased a certain definite fraction of the increase in brightness of its surrounding field in order that it should remain apparently equal in brightness to a second spot in constant surroundings. This work did not however touch upon the question of how far the visibility of detail or the distinctness of slight brightness-differences upon that test spot would be modified by the brightness of its surroundings. It is to this somewhat more practical question that the present work is devoted.

The Present Work

The plan of the present work is accordingly to measure the smallest visible detail and the smallest visible brightness-difference for a set of various conditions as complete as possible. The conditions reduced to their lowest terms and planned so as to be reproducible and capable of clear statement are (1) a test-field of constant size and measured brightness which shall be equal in the case of parallel visual acuity and brightness-difference estimations; (2) the surrounding visual field is to be filled as nearly as possible to its limits with surface of known brightness which shall be as nearly as possible uniform. The estimations of both visual acuity and smallest perceptible brightness-difference are to be made so as to cover every brightness for test-field on every brightness of background.

In order that there should be at the moment of exposure of the test stimulus as little visual disturbance as possible to the observer, it was arranged that he should, up to the instant of exposure, look at a uniform bright surface equal in brightness and area to the test-stimulus; and the apparatus was arranged in such a way that the lines of the acuity field, or the brightness difference in the case of the other, simply appeared upon the surface, other unavoidable changes in conditions being reduced to a minimum. At the end of the stimulus period the test-field was in a similar way returned to its condition as before exposure.

Method and Apparatus.—The observer sitting in the adaptation-room faced the test field, which was limited by a small rectangular opening in the wall separating him from the apparatus-room where the experimenter prepared the settings for each observation. Through the opening a uniformly bright surface was visible. When the experimenter signalled that everything was ready the observer at his convenience pressed a key which released a fall-screen behind the opening and exposed the stimulus in place of this bright surface. After three seconds the screen automatically dropped and the exposure of the stimulus was terminated by the reappearance of a uniform bright surface like the original. The judgment was then signalled to the experimenter who recorded it, pulled up the fall-screen, made a new setting, and gave the signal for the next observation. This was continued until a series of 16 judgments on 16 different settings given in haphazard order was finished. Then followed a pause of 3–5 minutes and a new series began. Four such series were made consecutively by one observer, two on brightness-discrimination and two on visual acuity. Then he exchanged places with the experimenter for another set of four series carried out at once under the same experimental conditions. The exact order of series in such a group of eight was determined by a scheme in which the two observers, *C* and *G*, each came as frequently first as second, and each of the two kinds of tests, acuity and brightness, occurred with equal frequency first and second for the individual observer. In the latter case (brightness-difference)

judgment was made on the right and left halves of the stimulus, in each one of the pair of series respectively, right and left each coming as frequently first as second. Finally the scheme provided for a representative distribution of the various brightnesses of the test-field over the whole period of experimentation.

In the first part of our work, which lasted from February to May, the observer was completely dark-adapted except for the amount of light admitted through the area of the test-field opening. The arrangement made possible seven different stimulus-brightnesses whose photometric values ranged between the highest securable and the lowest at which it was possible to work with our apparatus. For the second part, with light adaptation, which lasted from June to August, only five different brightnesses were used; the middle one of the previous seven being already too low for definite results. With each of these intensities 32 series of observations were made by each observer, 16 for brightness and 16 for acuity.

In order to secure uniform light adaptation, a wooden cube of 1 m. side was constructed whose inside corners and edges were cut off by oblique surfaces tangential to an inscribed sphere, so that the whole 26-sided figure approached the shape of a sphere. This was painted white inside. In one of the vertical sides of the cube, an opening was left for the observer's face and headrest. In the oblique surface directly above this was a sheet of milk glass, behind which was a 100-watt tungsten lamp, illuminating the white interior. Opposite the face-opening another smaller opening was made through which the test-field could be observed.[1] A heavy

[1] The dimensions upon which the appearance of the test-field and its immediate surroundings depend are

	Distance from Eye, Cm.	Actual Dimensions	Dimensions Projected at 2 Meters
Opening in back of cube.....	101	Width, 4.6	9.12
		Height, 3.4	6.74
Opening in wall at *T*, Fig. 1.....	181	7.1	7.85
		5.0	5.53
Prism face at *P*.....	200	8.0	8.0
		6.0	6.0

The opening at *T* therefore limited the apparent size of the field and the opening

black curtain behind the observer excluded all stray light from outside. In all experiments only the right eye was used. The left was screened off by means of a small ground glass. Before each series the right eye was given one minute for light-adaptation, but a minimum of 15 minutes for dark adaptation before a whole set of four series was required in

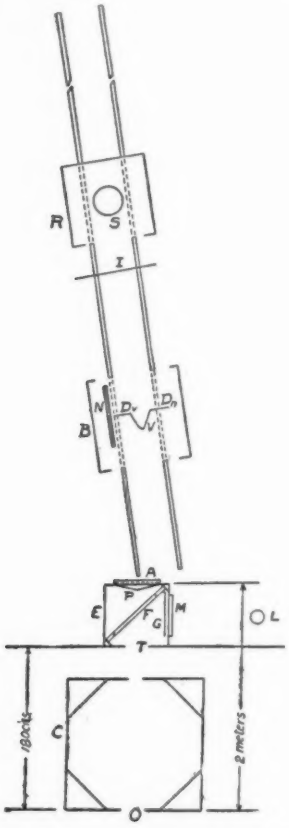

FIG. 1. General Arrangement of Apparatus.

the first part of the work, except in the case of the lowest stimulus-intensity when 25 minutes adaptation were allowed.

The arrangement of the apparatus is schematically repre-

in the back of the cube was large enough to leave a black margin not illuminated as the inside of the cube was. The result was that in the case of the bright surroundings the field, considered as at 2 meters distant was apparently 7.85 × 5.53 cm. in size and was seen as surrounded by a black margin of about 6 mm. apparent width.

sented in Fig. 1, which, however, is not drawn to a uniform scale. In this diagram *C* is the adaptation cube, with the observer's eye at *O*. The test-field is seen through the opening *T* behind which is the exposure-apparatus *E*. The stimuli are brought about in this way: Through a double-prism *P* the observer sees parts of the milk-glasses D_v and D_n so placed as to fill the right and left halves of the prism face and large enough to leave a margin to spare, so that the field halves appear to the observer as completely filled and perfectly uniform; and are seen in perfect juxtaposition at the obtuse edge of the prism in the center. D_v and D_n are illuminated by light diffused from a milk-glass screen *I* which in turn receives its light from *S*, a 500-watt tungsten lamp (110 volts) enclosed in a tin box *R* which can be slid to any position on the track. By a rack-and-pinion movement D_v may be adjusted on a small track, *N*, of its own, thus varying the distance of D_v from *I*, and differences in the brightness of the two halves of the field seen by the observer are so brought about. The face of the prism made a field of 6 × 8 cm. and it was situated 2 meters from the observer's eye.

D_v and D_n occupy openings in two black cardboard screens (one of which travels with D_v) joined by a velvet curtain *V* between them which is kept stretched in the position shown by a spring, and serves to keep D_v and D_n from diffusing light upon each other, as would otherwise happen in the extreme positions of D_v.

For the visual acuity a special test-object *A* composed of a system of opaque black lines of variable width separated by transparent spaces (5, 3) is placed just behind the double prism, so that in this case the lines are seen against the visible portions of D_v and D_n. When this is used D_v is moved to the point where the two halves of the field appear equally bright and the lamp *S* is advanced to compensate for the absorption of the test-object, so that the field shall be just as bright as for the parallel brightness-difference series.

The exposure is controlled by a fall screen *F* composed of two mirrors in a frame with a space between them. In the initial (upper) position the lower mirror cuts off the view of

the test-object and the observer sees in it the reflection of a third milk-glass *M* illuminated by the lamp *L*. When the observer presses the key the screen drops in its vertical guides and he sees the test-object through the interval between the mirrors, at the same time a small auxiliary screen *G* attached to *F* covers *M*. In three seconds the exposure is ended automatically by a special device, the screen falling so that the upper mirror is in the original place of the lower one, the screen *G* reëxposes the milk-glass *M* and the conditions immediately before the exposure are exactly reproduced.

Certain departures from the arrangement described were necessary. For the highest two intensities of the test-field the milk-glass *I* was removed so that the lamp *S* illuminated D_v and D_n directly, and the lowest brightnesses were obtained by replacing the 500-watt lamp with a tungsten lamp of 25 watts. Further, for the very lowest brightness the milk-glass *I* was covered with a diaphragm of black cardboard with a central square opening of 13 × 13 cm.

The three light-sources, *S*, *L* and the lamp in the adaptation cube, are in multiple on the same circuit and their voltage is kept constant. The current is supplied by a storage battery. Screens of black cardboard with suitable openings were hung between *S* and *I* (or where *I* was not used, between *S* and the two small milk-glasses D_v and D_n). D_v and D_n were protected from stray light by black cardboard walls *B* supported by a light framework, and by a black felt curtain on one side which the experimenter could raise to make the settings. As a further precaution against stray light the apparatus room was kept dark while the observations were being made except for the two lights *S* and *L*.

The photometric measurements necessary fall into three classes: (1) The absolute brightness of the field for the differential sensibility was in every case made the same as the brightness of the visual acuity field for the parallel set of observations. By making the lines too small to be seen (the brightness of the visual acuity field being unchanged by this procedure) the field appeared perfectly uniform, and

could be equated to the appearance of M by dropping the fall-screen until just the upper half of the test-object was exposed and seen against the lower half of M in lower mirror. Similarly by removing A and pushing the main lamp S away from I an equality between the brightness-difference field and M is reached. The position of S on the scale of the main track in both cases was noted and used in subsequent work at that brightness. (2) The value of the small differences between D_v and D_n was estimated by photometric determinations of the relative brightness of D_v as seen by the observer at three positions on its scale, made with the help of a Beckstein portable photometer (Strassenphotometer). The brightness was found to agree closely with the inverse square law, but owing to the distortion produced by the large size of I, the distance had to be measured from a point a definite distance beyond I. The three values for brightness of D_v checked up very consistently with the three distances when so measured, and consequently any small interval on the scale of D_v could readily be converted into an equivalent brightness-ratio.

Let r equal distance of D_v (so measured) when it appeared just brighter than D_n (as computed from the results) and similarly R equal distance for D_v just darker than D_n, D_n remaining constant.

Further let D_r equal brightness of D at distance r, D_R equal same at distance R and brightness of D_n equal D.

We have found by photometric measurement that

$$\frac{D_r}{D_R} = \frac{R^2}{r^2}.$$

But from Weber's law

$$\frac{D_r}{D} = \frac{D}{D_R} \text{ and consequently } = \sqrt{\frac{D_r}{D_R}} = \frac{R}{r}.$$

This then represents the ratio of two brightnesses that shall appear just different. The values given in the results are stated as $(R - r)/r$ or the fraction of stimulus increment for just-noticeable difference. Where I was removed as for the highest intensities the same procedure was used, except that

R and *r* had then to be measured from a different point for every different position of *S*.

3. The absolute brightness of the test-field was measured directly. By means of a single convex lens placed where the observer's eye would be during the experiments, the image of the test-field was thrown directly into the plane of the photometer, the screen of the photometer having been removed on that side. Readings were taken in this way, and again with the screen replaced and under the illumination of a standard lamp at 1 meter distance. From the data so obtained it was possible to get the brightness of the test-field in candles per square meter, by means of a coefficient for the instrument and method previously determined by using a surface of known candle-power per square meter.

In the first part of the work the brightnesses of the test-field were measured at the end of the set, the depreciation of the main lamp *S* known from measurements taken at the start and the values finally obtained corrected by one half of this amount to get the mean value used. In the second part the brightnesses were measured when the observations were just half completed and the values so obtained used without correction.

Unusual Appearances Referable to the Observers.—Certain appearances and feelings remain to be described, which because of their diversity cannot enter into the quantitative treatment of the results. These are described from memory and consequently without especial reference to the particular circumstances under which they occurred other than as stated.

At the high intensities *a* and *b*, especially *a*, and practically only with the dark surroundings, certain vague disturbances were experienced much like those felt after the removal of a trifling foreign body from the eye. They were perhaps more pronounced in the case of *C* than with *G*. The result was a feeling of blurring of vision and uncertainty as to judgment. No effort of will, or blinking or eye movements or waiting seemed to do away with this.

The brightnesses designated as *d* and *e* were the most

comfortable to the two observers *C* and *G* respectively when seen in the dark surroundings. The stimulus then appeared with the orange color of the light (at first only, according to *G*), if anything somewhat more pronounced than in the case of the higher brightnesses and overlaid (later, as *G* remembers) with a distinct grayish appearance. In the bright surroundings no such distinction as to comfort was made, at least, not so definitely as to occasion remark in any case. Although at the lower intensities and in a greater degree with bright surroundings the particular test-feature (lines or brightness-difference) was less easy to see positively, according to the numerical results, there was no especial difficulty or feeling of uncertainty on the observer's part. At the close of the test-period he was as a rule promptly ready with a definite judgment. Where the bright surroundings were used, the test-field, when less bright than the surroundings, appeared to be a gray varying toward a black as lower brightnesses were used. With the bright surroundings the lowest intensities used in the dark were impracticable, as the surroundings deepened this gray into a black so profound that the limitations of the apparatus were reached before a brightness-difference could be made observable.

At the very lowest brightness *g*, with the field seen in the dark surroundings, there was great difficulty from the appearance of shadows which seemed to have their origin somewhere in the visual apparatus of the observer. What seemed to be waves of blackness would sweep over the field like smoke at unexpected times, completely obscuring it from vision, the field being perfectly visible in the intervals as a dim rectangle of somewhat blurred outline. In some cases the black appearance would seem to start from one margin of the field in a dense stream and slowly spread over it, suggesting the appearance of ink being flowed over a surface. At other times as noted by *C* the field would seem to pulsate slowly, varying as a whole between its clearest appearance and obscurity. It was impossible to anticipate these disturbances, or to suppress them in any way. The difficulty was solved by

increasing the adaptation-time to 25 minutes under the experimental conditions. After that time the eye was practically free from such disturbances and observation could go on satisfactorily with an occasional short wait.

As to the visibility of the test-feature of the field something is to be said. In the case of both lines and brightness-difference, instances were observed which showed that these could be visible at the first moment of exposure, or could appear after an interval. On the other hand, they might disappear during the test-period after having been clearly visible. In the case of brightness-difference, the apparent inequality of brightness of the two halves of the field would not infrequently change its direction while actually under observation. This is actually described in the notes of the experiments to occur at the lower brightnesses, namely, in the case of observer *C* at brightness *c*, and observer *G* at the lowest brightness, *g*, where a number of the exposures were described as 'all reversibles, some of them changed several times.' The judgments in these particular instances were rendered 'equal,' this word being used to express judgment on the indeterminate cases.

Results.—The data were computed by the method of limits, that is, the critical values of the individual series of sixteen judgments were averaged with those of the other series for the same conditions to get the final values.

The visual acuity series gave in this way one final value for each set of conditions representing the average setting of the acuity object at which the lines became visible. The brightness-difference series gave two, corresponding to the positions of D_v on the scale N_1 at which the variable half of the field became appreciably brighter and darker, respectively, than the comparison half. The brightness-ratio was then computed from these two mean positions of D_v and the result expressed as the ratio of the absolute brightness-difference to the absolute brightness of the less bright half of the field at which the difference became noticeable. This is designated simply *L* (limen) in the results.

In addition to this, the brightness-difference series were

computed in a similar way on the basis of the length of the entire region of mixed judgments as obtained from the individual series and averaged similarly to the above. The final value obtained is expressed similarly, as a quotient (M) and is used because it shows evidence of certain confusions of vision that appeared in some instances, and which are eliminated from account by the method of limits.

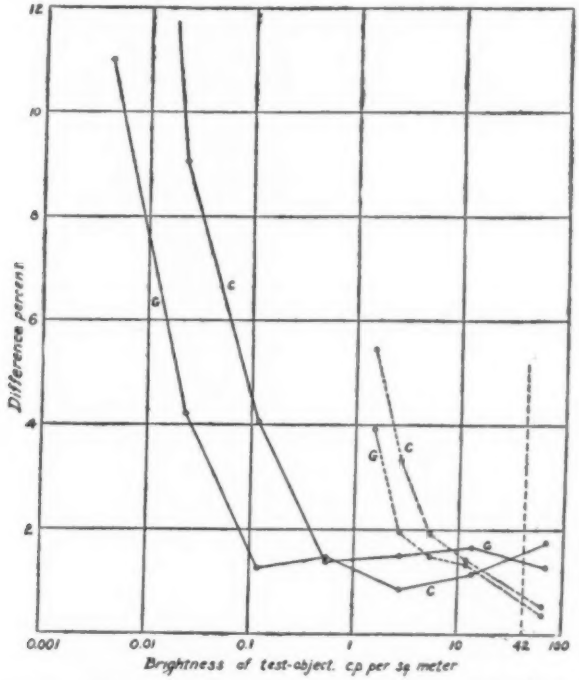

FIG. 2. Extent of the Region of Mixed Judgments (M Values) for the Two Observers under Various Conditions.

Dark surroundings ————————————

Surroundings 42 candles per sq. meter - - - - - - - - - - - - - -

The final results are given in Table I. and graphically represented in Figs. 2 to 6, where the subscript 1 denotes the curves of the values obtained with dark surroundings, and the subscript 2 those of the values obtained when the surroundings had a brightness of 41.9 candles per sq. meter, these latter being represented by the curves drawn in broken

TABLE I

VALUES OBTAINED FOR VISUAL ACUITY AND DIFFERENTIAL SENSITIVITY WITH TEST-OBJECT AT VARIOUS BRIGHTNESSES AND SURROUNDINGS (1) DARK AND (2) FILLED WITH BRIGHTNESS OF 41.9 CANDLES PER SQUARE METER

The upper figures in each case give the result for observer *G*, the lower for *C*. At *b*, *β*, *c* and *γ* of the set with bright surroundings only 14 series are represented at each point owing to breaking of lamp.

Test-Object Brightness			Surroundings Dark							Test-Object Brightness		Surroundings 41.9 Candles Per Sq. Meter							
Designation	Candles per Sq. Meter	Log. of Same	Relative Visual Acuity	Mean Var., Per Cent.	Visual Angle, Minutes	Diff. Limen, Per Cent.	Mean Var., Per Cent.	Mixed Region, Per Cent.	Mean Var., Per Cent.	Candles per Sq. Meter	Log. of Same	Relative Visual Acuity	Mean Var., Per Cent.	Visual Angle, Minutes	Diff. Limen, Per Cent.	Mean Var., Per Cent.	Mixed Region, Per Cent.	Mean Var., Per Cent.	
a.....	68.3	1.834	4.35 4.23	2 5	0.62 0.64	0.37 0.23	84 107	1.77 1.28	52 61	64.3	1.808	4.77 4.42	3 5	0.57 0.61	0.19 0.22	79 100	0.37 0.56	56 62	*a*
b.....	13.46	1.129	3.99 3.69	2 4	0.68 0.73	0.46 0.40	79 57	1.14 1.67	57 50	11.96	1.078	4.18 3.82	3 3	0.65 0.71	0.55 0.77	48 60	1.33 1.41	45 33	*b*
β.....										5.25	0.721	3.80 3.50	5 4	0.71 0.77	0.36 0.90	85 43	1.48 1.91	48 29	*β*
c.....	2.70	0.432	3.60 3.36	4 5	0.75 0.80	0.41 0.37	78 82	0.87 1.50	56 47	2.71	0.433	3.06 3.01	6 4	0.88 0.90	0.63[1] 1.70	63 45	1.96[1] 3.31	61 41	*c*
γ.....										1.51	0.178	2.85 2.65	5 5	0.95 1.02	1.03 3.71	102 55	3.91 5.44	37 62	*γ*
d.....	0.542	9.73	3.13 2.89	3 7	0.86 0.93	0.38 0.40	67 73	1.47 1.40	37 38										
e.....	0.118	9.073	2.50 2.52	4 6	1.08 1.07	0.46 1.47	100 50	1.24 4.04	73 29										
f.....	0.0232	8.365	1.81 1.54	5 6	1.49 1.75	2.31 4.57	55 40	4.20 9.08	47 31										
g.....	0.00437	7.640	0.91 0.69	13 12	2.97 3.91	6.57 12.18	41 37	11.0 25.7	32 22										

[1] One series omitted as it gave widely divergent results. Including this the values are 0.82 and 2.29 respectively with mean variations of 70 and 65 per cent. The mean variations are all expressed per cent. of respective values.

lines. The values for visual acuity were also computed so as to be expressed as least visual angle in minutes (center of dark band to center of adjacent bright one) which latter values alone appear in the curves designated *V* in Figs. 2, 3, 4 and 5. The abscissæ (brightness) are plotted logarithmically although the figures given at the ordinates drawn in are the

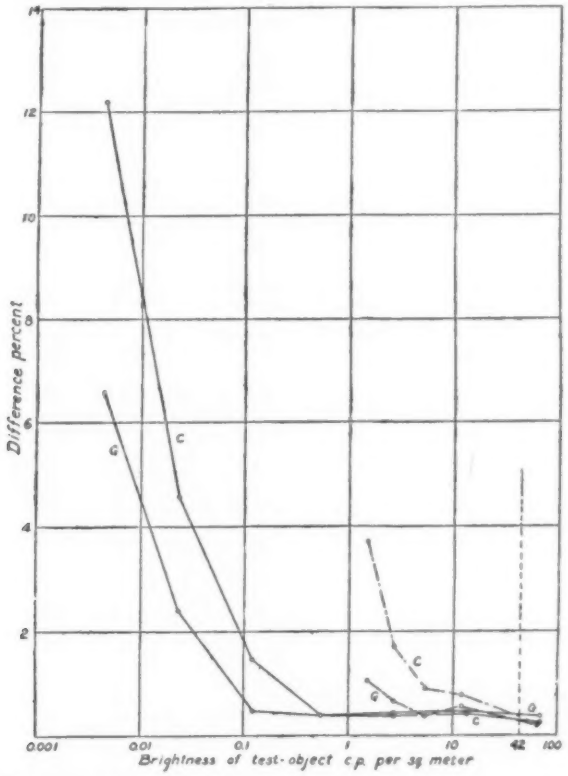

FIG. 3. Difference-limen (*L* Values) for the Two Observers under Various Conditions.

Dark surroundings ————————————

Surroundings 42 candles per sq. meter — — — — — — — — — —

actual numerical values. Hence, the logarithmic values for brightness, given in the second column of each half of the table, are the actual plotted abscissæ for the points representing the observed values.

Comparison of the results of the two observers shows that for equally distinct vision at the lower intensities observer *C* required a distinctly higher brightness of the test-object than did *G*. This difference held consistently throughout. In the dark surroundings the curves (Fig. 2) indicate that for equal *M*-values *C* required under these conditions a test-object about 4.25 times as bright as *G*, and for equal *L*-values (Fig. 3) about 2.9 times. Owing to the fact that the two *V*-curves

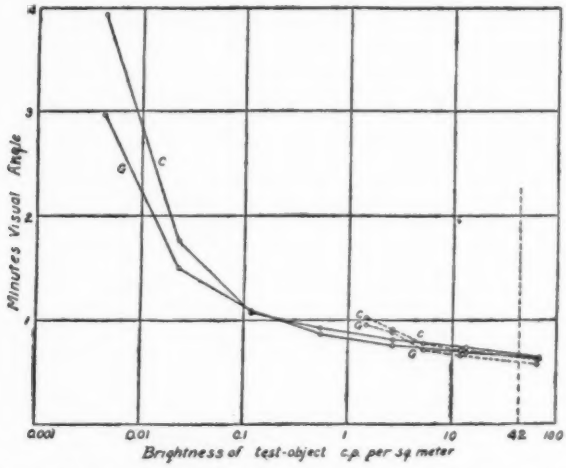

FIG. 4. Least Visual Angle (*V* Values) for the Two Observers under Various Conditions.

Dark surroundings ————————————————

Surroundings 42 candles per sq. meter - - - - - - - - - - - - - -

do not run anywhere near equi-distantly in this region (Fig. 4) no such quantitative estimation can be made with respect to the *V*-values. The divergence of the curves persists to brightnesses as low as any used, and this divergence indicates difference in visual discrimination in the same sense as the differences in the two cases of the M_1 and L_1 curves. At the lowest point possible to estimate by the curves the brightness-ratio for equal distinctness of vision is in the case of the V_1 curves 1 : 2.1 (Fig. 4) and the appearance of the curves suggests that it would have increased if lower brightnesses had been used.

Where the bright surroundings were used, the curves indicate differences between the two observers in the same direction as in the case of dark surroundings, although in the case of the M_2 values alone can the difference be quantitatively

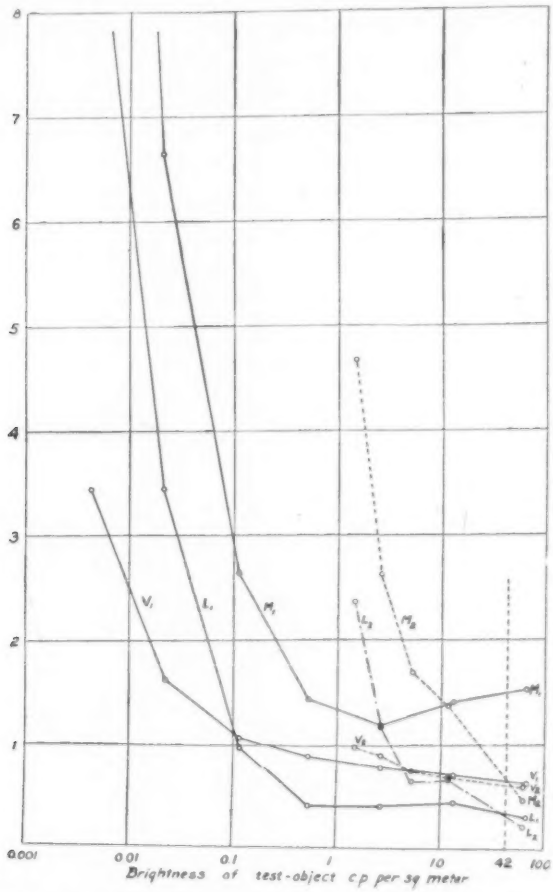

FIG. 5. Mean Values of M, L and V under Various Conditions.
Dark surroundings ————————
Surroundings 42 candles per sq. meter { - - -

roundings were used. In the case of the L_2 values, however, the individual difference between the two observers does not appear on inspection of the curves to be less with bright surroundings than in the case of the dark, and the visual acuity estimations with bright surroundings were not carried to low enough brightnesses to show any distinct individual differences in vision under these conditions.

As to the all-around difference between the two observers, further than the fact that *G* showed better visual acuity than *C* (Fig. 4) at every point except one, the differences are not consistent enough to merit especial mention and can easily be made out by a glance at the curves.

The manner in which vision depends on the brightness of the test-object and the presence or absence of its bright surroundings is shown in Fig. 5 where the values obtained from the two observers are averaged for each set of conditions. The quantities representing brightness-difference of the two halves of the test-object are then plotted as difference per cent. of the less bright field-half, and the visual acuity halves as visual angle in minutes, all on the same scale.

First, with dark surroundings it is seen that the difference-limen (L_1) is nearly constant for the higher brightnesses of test-object, and at a certain point begins to increase rapidly as the test-object is made less bright. This result is quite similar to the result obtained by Koenig. The M_1 values correspond fairly well with these—with less consistency at the higher brightness of test-object. The curve indicates at the highest brightnesses of the test-object *a* and *b* a higher value for *M* than in the region below this, which implies a less degree of certainty of vision at these highest brightnesses as seen in dark surroundings.

It will be remembered that Koenig's results showed that up to its maximum value (about 1.7) visual acuity increased by equal arithmetic intervals for equal geometric intervals of brightness, *i. e.*, with the logarithm of the brightness, and that the curve showed two rates of increase, a slow rate, from the lowest brightness up to a point where vision was about 0.14, and then a rapid one. Thus, plotted on logarith-

mic (brightness) abscissæ the curve was a broken straight line, with the convexity of the angle facing downwards.

The present visual acuity observations have not been carried to as low brightness as those of Koenig, as shown by the fact that the lowest value obtained for visual acuity in the present work is about 0.29 (Fig. 6). The results here

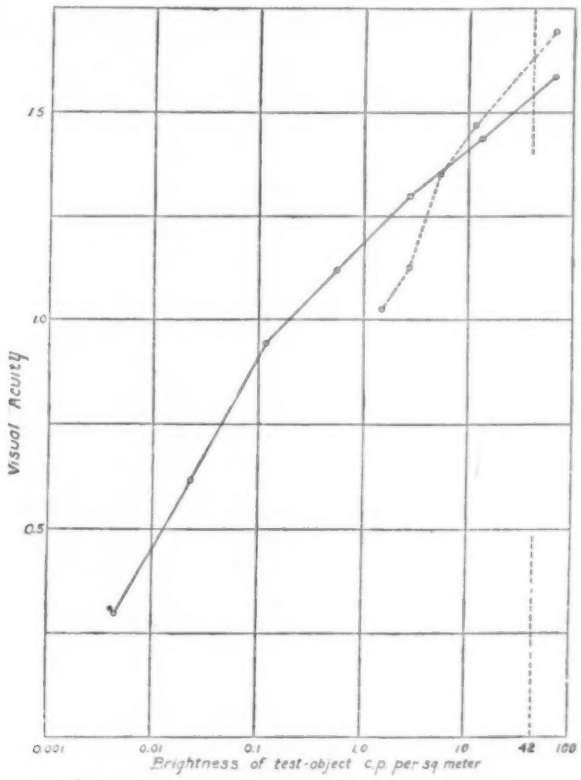

FIG. 6. Mean Visual Acuity under Various Conditions.
Dark surroundings ————————————
Surroundings 42 candles per sq. meter - - - - - - - - - - - - - -

presented consequently show nothing as to this feature of the visual acuity function. The results do however, as far as they go, deviate from the straight line which is the assumption Koenig felt justified in making as to the course of visual acuity when the brightness was plotted logarithmically. In

Koenig's work a test-card was used illuminated in the ordinary way, that is, seen by reflected light, and the illumination was changed by using different light sources and by varying the distance of these from the test-card. It is not stated by him that any especial precaution was taken to restrict either the illumination or the vision of the observer to any limited area of the test-object and unless such precaution was taken an area of considerable extent about the test-object itself was visible as brightness of the same order of magnitude as the test-object. This may account in part for the difference between his results and the present ones since (to anticipate a little) in the present work where bright surroundings were used, the effect was to make the curve steeper (Fig. 6, dotted line) which, if the surroundings in each case were nearly proportional to the test-object brightness, would make the curve more nearly a straight line. Still, from the results given in Fig. 6 it does not seem that an absolute straight line would be reached, but appears that there would still be a slight bend in the same sense as that of the curve for dark surroundings throughout.

Two results are shown as the consequence of substituting bright surroundings for the dark. One is that the brightness necessary for equal distinctness of vision near the lower limit is much greater in the case of bright surroundings. The lower limit of vision is, as it were, pushed up to a higher brightness by the bright surroundings. This shows clearly in the curves M_2 and L_2, and is clearly intimated for visual acuity by the deviation (in the same sense) of V_2 from its mate V_1. These facts correspond to the perhaps more familiar one that a test-object clearly visible out of the dark may be practically extinguished when bright surroundings are thrown about it. As a result of this, the lowest brightnesses which afforded perfectly practicable conditions when seen out of the darkness had to be abandoned when bright surroundings were used.

The second result of the bright surroundings is shown by the values obtained with the test-object at brightness *a*. Here in every case (and the result was also the same for each

of the two observers) vision showed a distinctly more favorable value when the bright surroundings were used than it did with dark surroundings under otherwise identical conditions as to the test-object itself.

Summary

The results of the present work indicate the following:

1. Different individuals may show fairly wide differences in their vision of objects of very low brightness, both with and without bright surroundings. For the two observers of the present work this difference is in all cases in the same direction.

2. In spite of such individual differences the relative changes in visual capacity caused by differences in surroundings were found for both observers to be on the whole in the same direction in cases of the same change in the conditions.

3. For objects of relatively low brightness, the presence of a surrounding field of relatively high brightness has the effect of lowering the capacity of vision both for detail and for brightness difference.

4. In the case where the surrounding field was slightly brighter than the test-object visual discrimination was found to be actually better for both observers and by both criteria than for a physically identical object seen in dark surroundings.

Addendum by Percy W. Cobb

As seen from the table, the mean variations of the results as to brightness-difference (limen and region of mixed judgments) are very large as compared with the corresponding brightness-differences themselves. This made it appear advisable to repeat that portion of the work where the behavior of vision showed comparatively small divergences between dark and bright surroundings on which to base conclusions. This included the determinations with test-object-brightnesses *a* and *b*, and was accordingly done by one of the authors of the foregoing assisted by Dr. H. M. Johnson.

The whole period of experimentation for these results extended from February 6 to March 10, 1913. The procedure was the same as in the foregoing, except that the box *C*, which furnished the surroundings for the test-field, was in place both for bright and dark surroundings. In the latter case it was only necessary to extinguish the light which illuminated its interior to get perfectly dark surroundings. The procedure was modified in one further detail, in that the series taken with bright surroundings and those with dark were both distributed over the whole term of experimentation according to a plan such that dark and bright were each represented over the whole of the period.

TABLE II

REPETITION OF INVESTIGATION UNDER CONDITIONS APPROXIMATING *a* AND *b* OF TABLE I

The upper figures in each case give the result for observer *C*, the lower for *J*.

Test-Object Brightness			Surroundings Dark							Surroundings 35.4 Candles per Sq. Meter						
Designation	Candles per Square Meter	Log. of Same	Relative Visual Acuity	Mean Var., Per Cent.	Visual Angle, Minutes	Diff. Limen, Per Cent.	Mean Var., Per Cent.	Mixed Region, Per Cent.	Mean Var., Per Cent.	Relative Visual Acuity	Mean Var., Per Cent.	Visual Angle, Minutes	Diff. Limen, Per Cent.	Mean Var., Per Cent.	Mixed Region, Per Cent.	Mean Var., Per Cent.
a . .	79.24	1.899	3.74	4	0.72	0.54	67	1.49	39	3.96	4	0.68	0.32	68	1.14	28
			5.30	2	0.51	0.24	98	1.09	52	5.57	2	0.49	0.22	98	0.78	47
b . . .	13.95	1.145	3.32	6	0.81	0.19	102	0.67	56	3.56	5	0.76	0.52	71	1.19	69
			4.91	2	0.55	0.27	74	1.05	47	5.02	3	0.54	0.17	97	0.70	67

Table II. gives the results obtained. An individual difference worth noting is that observer *J* gave on the whole better results than *C*. This is striking in the case of visual acuity, and uniformly true as to brightness-difference except at brightness *b* with dark surroundings.

As to the differences in vision due to the state of the surroundings, it will be seen from the table that for observer *C* the results are the same in direction as in the case of brightnesses *a* and *b* in the foregoing. That is, visual acuity is better for bright surroundings at both points, and differential sensibility better at *a* and worse at *b*.

Observer *J*, however, gave results different from either *C* or *G*. His results were better in all respects with bright surroundings at both *a* and *b* than in the corresponding cases with dark surroundings.

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THEORETICAL AND EXPERIMENTAL STUDIES IN THE MECHANISM OF SPEECH

BY ANNA WYCZOIKOWSKA

The experiments described in this paper were suggested by certain general convictions concerning the thought processes (including here the mechanism of speech). I shall present first a short account of these convictions before passing to the anatomical and experimental parts of the paper.

If we submit an elementary thought process to close analysis, three different stages in its development are to be discovered: (*a*) The automatic start of the processes of attention which is observable in the beginning of every thought process; (*b*) the expectation of the effects of this development of automatic attention; and (*c*) the spread of the inward neural tension, underlying the process of attention, until it issues in the form of speech and gesture.

(*a*) The automatic start of the organic process connected with attention involves in every thought process, on the one side, the inhibition of activity in certain groups of muscles, and on the other the facilitation of activity in certain other groups of muscles. If we are reading a sentence for instance while in the attitude of willingness to understand, we keep still, cease to walk and to move, obviously for the sake of eliminating every other object which might catch and hold attention. The expressive movements, on the contrary, indicate the rise of the thought activity; the forehead frowns, vision is concentrated, and the upper muscles of the face are stimulated. According to Sante de Sanctis[1] three muscles assist the thought process: the frontalis, orbicularis palpebrarium, and superciliaris. At the same time, it is well known from experimental researches, that various organic changes appear in respiration, circulation and blood pressure,[2]

[1] 'Mimik des Deukens.'

[2] Angell and Thompson, Binet and Henri, Lehman, MacDougall, Meumann, Mosso, Monasterio, Ribot and Vaschide.

as well as in the movements of the pupil,[1] the length of the individual reaction,[2] etc. Although consciousness plays no part either in the inhibition or the facilitation of activity in the expressive movements, the movements seem to be the main factors in the display of every thought process.

(*b*) The second stage of the thought process is characterized by a kind of unconscious tension and by the expectation of the results to follow upon attention. Both features of this stage can be observed in those children and adults who have more or less of the capacity for abstract thinking. Thus a young person of little culture, asked to write a letter, enters into a state of attention and says after waiting a while: "My head is absolutely empty; I have no idea of what to write." A child of six and a half years, asked how much is 5×5, answers immediately twenty-five; but when asked how much is 9×9 it waits a while, changes the method of attack, grasps a piece of chalk and writes upon the blackboard:

$$\begin{aligned} 3 \times \ 9 &= 27 \\ 3 \times 20 &= 60 \\ 3 \times \ 7 &= 21 \\ &\overline{81} \end{aligned}$$

We see in the first example the maximal, in the second the minimal time of this expectation of the results of the display of attention. In the third example the disagreeable feeling probably of the fruitless expectation suggests to the child a change of arithmetical manipulation, and especially a series of consecutive passages from the known to the relatively unknown, until the required problem is solved. At every stage of the evolution of the thought process the unconscious moment is exchanged for a conscious one. Attention starts unconsciously before the special questions are clothed in words of how much are 3×9, 3×20 and 3×27; alike unconscious are the moments of expectation until they are resolved in the numbers 27, 60, 21, etc. The first truly conscious words and numbers are 3×9, 3×20, 3×7 or

[1] Heinrich, Mentz.

[2] Vaschide et Raymond Meunier.

27, 60, 21 and 81. We are thus entitled to affirm that this involved process which is manifested in starting attention automatically as well as in expectation of attention's results is absolutely unconscious. The conscious moments appear first when the impulses of the thought process enter into a near connection with the word or its symbolic equivalent. Sometimes we do not find readily the exact word for our thought process, but we already have the potential feeling of it. Secondly we can say that the thought process is a continual passage from the unconscious into conscious stages of mind until it acquires the form of a word.

It is to be added that this thought process must be in continual contact and in close relationship with what we may call, in the absence of a better expression, the organic storage of past experiences.

(*c*) The third stage of the thought process is characterized by the appearance of the articulate word-form which seems to intellectualize definitively the thought process. As long as the impulses connected with the starting of attention do not stimulate the tongue, the mouth, the lips and other speech organs to engage in synthetic action and as long as the radiation of reproductive movements[1] connected with the meaning of the words does not appear, the thought process does not enter into its final or intellectual stage of development.

But concerning this third moment in the display of the thought process a new distinction has to be made, especially between (*a*) the spoken word, which is the effect of the individual thinking, and (*b*) the word which is heard when spoken by another person. In the first case the speech process is preceded by the above described start of mechanical function of the muscles together with changes of respiration, circulation, etc., all of which dispatch the necessary impulses to the organ of speech; in the second case, on the contrary, the hearing of a word precedes the start of automatic attention for the exact comprehension of the heard word. We have thus to add some details concerning this second case, namely the mechanism of speech through which we hear and understand the speech of other persons.

[1] Steiner.

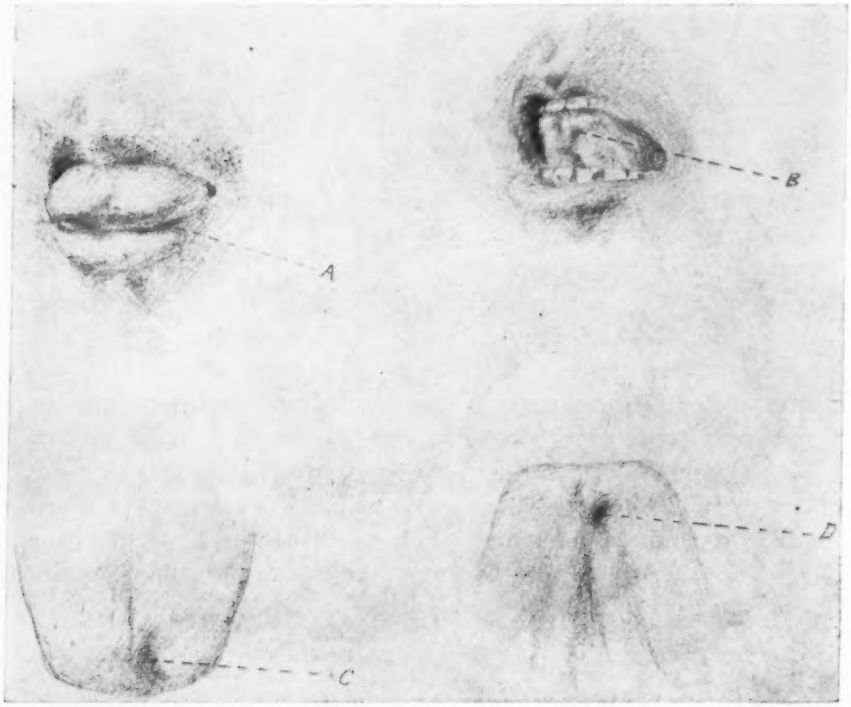
Every word pronounced aloud acts upon the ear and the tongue of the hearer in a way similar to that in which a vibrating tuning-fork acts upon another fork, provided both contain the same number of vibrations. The ear and the tongue of the hearer enter into what the Germans call a 'Mitschwingung,' or sympathetic vibration with those of the speaker. They do not enter into this state of vibration of themselves but are forced into it by the stimulus of the spoken word. Only when the stimulus coming from the voice of person *A* incites mechanically the same coördinate movements of the organ of speech of person *B* is the latter able to understand the word spoken and heard. This means however that one does not completely understand the word that is spoken to him until it is repeated by his own organ of speech (although in a more simple way). Without this kind of sympathetic vibration in our speech organ, we should never be able to follow closely and understandingly the speech of another person. Words, whether spoken or written, furnish only a combination of impulses sufficient to stimulate the function of speech or of writing within our own organism. Conscious understanding follows upon these intraorganic processes. The experiments which will be next described refer to some unconscious phenomena of the thought processes and especially to the movements of the tongue under the impulses of the hand and of the ear.

II

In Paris, 1901, I noticed a particular connection between the movements of the tongue and those of the right hand. At first they seemed to be only of clinical importance. Later, when giving attention to lingual phenomena in relation to mental, I reverted to them. I observed that whenever the person *K* pressed together the right thumb and index, there arose at the end of her tongue a small cavity within the texture of the muscle. It was near the medial line and could be observed only on the left side. It disappeared regularly when the pressure of the two fingers ceased, and reappeared when the pressure was reëstablished. A similar cavity can

easily be produced by pressing the end of the tongue lightly from above and beneath with two pencil points.

The phenomenon was so obvious in *K* that Mr. E. Lewy, a notable Polish painter, was able repeatedly to sketch it. Fig. *A* represents the cavity from above, Fig. *B* from beneath. Figs. *C* and *D* give an anatomical view.



The following questions then arose: (1) Do such lingual movements stand in fixed relations to movements of other fingers? (2) Are they normal or clinical? (3) Are they merely associated nervous phenomena, or do they indicate some direct phonetico-graphical transmission?

The answer to the first question was soon reached. Many observations showed that no finger except the right thumb is able to stimulate the lingual reaction. But the thumb will do so when pressed against any other finger of the right hand. Furthermore, there need be no pressure of the

thumb tips, for stimulation of the *thenar* eminence will produce the same effect. The lingual reaction is evidently due to some musculo-nervous activity of the *thenar* eminence.

Results of experimentation with the second question were at first negative. There was no such obvious synchronism of pressure and cavity as in *K* in the other persons tested. But longer experimentation has shown that there is always some reaction. At the point of the tongue indicated in Figs. *A* and *B* a magnifying glass will always detect some movement. It is more easily observed beneath than above, and more regularly in neurasthenics than in normal individuals. Finally, a person often subjected to experiment declared that he felt some slight sensations at the tip of the tongue. The marked cavity must be regarded as pathological, but it led to establishing a fixed relation between the hand and the tip of the tongue.

The third question involves histological considerations, and will be taken up later in this study. But first we may describe a second series of experiments.

III

In the winter of 1907–8 I was enabled to pursue in the psychological laboratory of the University of Chicago certain experiments with graphic methods. Tongue movements were recorded on a revolving cylinder when certain words were thought or said. The apparatus was simple—a sort of flattened wine glass as a receiver, a Marey tambour with a longish pen, and a Ludwig kymograph. The glass, which was large enough to admit the end of the tongue without impeding its movement, was prolonged as a tube, which was connected with the tambour by a rubber tube. Glass and tambour were fixed, and the pen rested upon the cylinder of the kymograph.

Records were obtained of lingual movements (1) when the subject thought of some familiar verse; (2) when he thought about the words 'experimental psychology'; (3) when he heard the same words as in (2); (4) when he remembered a well-known melody with or (4*b*) without words; (5) when he

listened to a sounding fork; (6) when he listened to a patriotic melody under suggestion; (7) when he remembered a melody under (slight) hypnosis.

The results are shown in the appended nine plates. Every thought produced some movement of the tongue. Very characteristic is the curve of Miss W. as she remembers the verse of C. Palmore, "When I am dead, my dearest, sing no sad songs for me." So too are the curves produced on hearing the words 'experimental psychology,' pronounced—I regret to say—with a foreign accent. *Thinking* these words produce virtually the same curve as *hearing* them, though thinking shows greater intensity of impulse. This may be seen by comparing curve 2 with curve 3.

The exaggeration of the curves produced by a patriotic song is obvious. So is that of the melody remembered under a slight hypnosis. The curve of a melody with words differs from that of the melody without words, as may be seen in curves 4 and 4*b*. Special interest attaches to the curve of the sounding fork heard by persons of the auditive type, curve 5.

These experiments incontestably show the synchronism of tongue movements with thought. But they were reinforced by introspection. Every person affirmed that when thinking or listening to speech or melody he was aware of tongue movements. Dr. W. says: "I follow with my tongue the syllables of the words as they are spoken." Mr. S. felt certain movements in the tongue, but adds: "It is not a movement, but a tendency to move the tongue." Mr. J.: "It seems that there are movements, but there are not. These movements are more external." It reminds us of the words of A. Stricker:[1] "Die Articulationsorgane bewegen sich nicht beim denken, aber es geht in den Muskeln etwas vor, was dem Vorgange beim wirklichen Aussprechen innerhalb einer gewissen Grenze ähnlich ist." Stricker has made similar observations with a German actor, and arrives at the conclusion that thinking is always accompanied by the feeling of movements of the throat and tongue.

[1] 'Die Sprachvorstellungen,' p. 16.

In my experiments every person was able to specify where in the tongue the movements were felt. The tip was nearly always specified, and often the back or the root. Listening to a melody is frequently accompanied by strong impulses at the base of the tongue. Some persons felt the musical rhythm on the sides of the tongue. Mr. J. says: "Every accent is felt in the tongue." Mr. P.: "The impulses are stronger on the sides of the tongue."

IV

Passing now to the explanation of the two kinds of kinetic phenomena described under II. and III., we turn our attention to some anatomical details in the topography of the nerves supplying the tongue. I am aware of the danger of superficiality in such a study. However, I am inclined to publish certain observations which I have made, even if they are not absolutely exact, in the hope that they will suggest new corroboration of the facts stated.

1. Concerning the movements of the tongue under the influence of special movements of the hand, we note first that the hypoglossus, the special motor nerve of the tongue, and its main branch the communicans noni, are in strict connection with the first four cervical nerves; namely, the hypoglossus with the first and second, the communicans noni with the third and fourth. It is of importance that the fourth cervical is anastomosed with the fifth, which chiefly supplies the hand; likewise it sends a branch to the communicans noni. We notice this nervous connection as a possible tract between the hand and the end of the tongue, which could explain the transmission of the described movements of the thenar eminence to the end of the tongue.

This seems the more probable because the nerve supplying the hand—the median, which receives the branches of all the anterior roots of the cervical nerves—enters into special junction with a second nerve of the hand, the cubital. These two nerves anastomose by a fine thread in the forearm, between the flexores digitorum. Then the median keeps on to the middle of the hand, and the cubital to its side. But,

it is of interest that they again anastomose in the thenar eminence, the mutually opposed muscles of which they supply. The median descends the inner part of the arm, buries itself behind the aponeurosis of the biceps, and goes through the two fasciculi of the pronator teres. Lower down it divides into five branches which supply the muscles of the thenar eminence as well as the thumb, the index, the middle finger, and the outer part of the ring finger. It gives off filaments to the palm. The cubital nerve, formed by the last two or three nerves of the cervical plexus, runs down to the hand, supplies the last two fingers and through one of its branches crosses the palmar surface, leaving the side of the ulnar in order to reach the thenar eminence. Thus the median supplies the short and long abductor and the opponens, the cubital extends its terminal ramifications in the adductor pollicis. The latter as we know is a large fleshy muscle forming the deep underground of the thenar eminence. It presents the form of a triangle with the apex to the first phalanges of the thumb, and its base to the metacarpal of the third finger.

When we consider the form and function of the adductor pollicis, fixed between the third metacarpal and the thumb to bring these fingers near or apart, and when we consider farther the second deep anastomosis of the median with the cubital, we can hardly resist conceiving the hypothesis that there exists an organic-kinetic structure of a combined action in which the thenar eminence presents the exterior station while the end of the tongue seems to be its correlative interior kinetic station.

We notice the coincidence of this assertion with the experimental result of Beevor and Horsley. Experimenting on monkeys they found that stimulation of the frontal lobe and the capsula interna produces movements of the tongue and of the thumb.

But leaving the perilous way of this hypothesis we only state that there exists a nervous connection between the thenar eminence and the cervical plexus on one side, and between the cervical plexus and the tongue on the other,

and these nervous conditions support the results obtained in the first series of experiments. It is now clear why the pressure of the thumb against the index, and the stimulation of the thenar eminence, produce certain unconscious movements of the end of the tongue, represented in Figs. *A* and *B*.

2. We pass now to the anatomical details concerning the second kind of lingual movements, which arise under the influence of speech heard, thought, or sung, as described under II.

The tongue is supplied as we know by two other nerves, the lingual and the glossopharyngeal. Both of these are also connected with the ear. The lingual, a nerve of taste containing also some motor fibers, is joined in its lower portion with the chorda tympani (a branch of the facial) which in its upper course penetrates the membrana tympani of the middle ear. The lingual connected to the chorda spreads with its end ramifications from the inferior to the superior surface of the tongue as well as to its sides, connecting in this indirect way the tongue with the ear. Not less obvious is the connection of the glossopharyngeal with the ear. It is a nerve of taste and of general sensibility, with some motor fibers, and supplies the back of the tongue. In its upper region the glossopharyngeus sends up a vertical branch called the Jacobson nerve, or the tympanic nerve, because it enters into the tympanic cavity, where it spreads with many ramifications and enters the fenestra ovalis, the fenestra rotunda, and the acoustic tube.

Thus we see that the glossopharyngeus with the Jacobson nerve seems to be in no less intimate connection with the ear than is the chorda tympani.[1] The first comes in contact with the fenestra ovalis and the fenestra rotunda, the second with the membrana tympani.

Considering the strict connections of both with the tongue also, we more easily understand why some persons attest that they hear somewhere the words while thinking, or feel a

[1] The chorda tympani is recognized as a vasomotor. Should it be so, we can assume that this primitive function of the chorda, modified by the stimuli of the ear, can promote simultaneously an innervation of the tongue for the purpose of the speech heard.

kind of *vibrating motion* at the end of the tongue or at its back and side when listening to the same words or tones. Mr. J. hearing the words 'experimental psychology' says, "I feel strong impulses at the back of the tongue; my tongue has the tendency to move forward." Again Mr. S. says, listening to a melody, "I feel more movements at the back of the tongue." And Dr. W., "There is a feeling of rhythm—a wave motion—as I successively visualize the different parts of the two words. I feel movements on the end, often on the basis of the tongue." This functional connection of the nerves supplying the tongue with the ear is probably of importance in the assimilation of the speech heard.

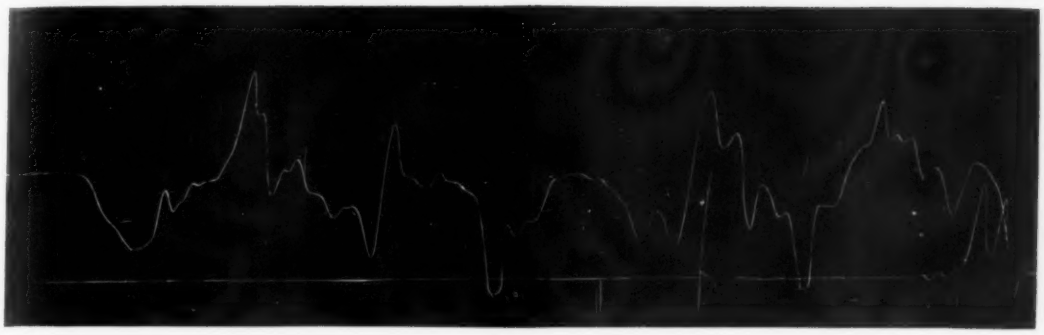


FIG. 1.
Miss W. "When I am dead, my dearest,
Sing no sad songs for me."

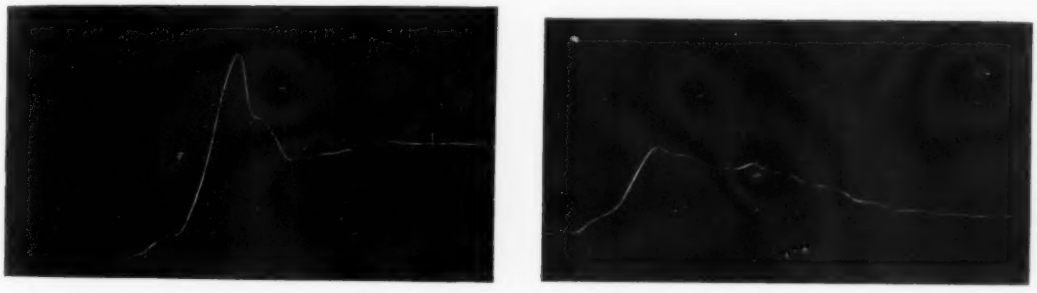


FIG. 2.
Exp. Psychol.

FIG. 3.
Exp. Psychol.

FIG. 4*a*.
"Go tell aunt Rodie."

PLATE I.

FIG. 4*b*.
Without words.

FIG. 5.
Sounding fork.

FIG. 6.
"Boze cos Polske" (patriotic song).

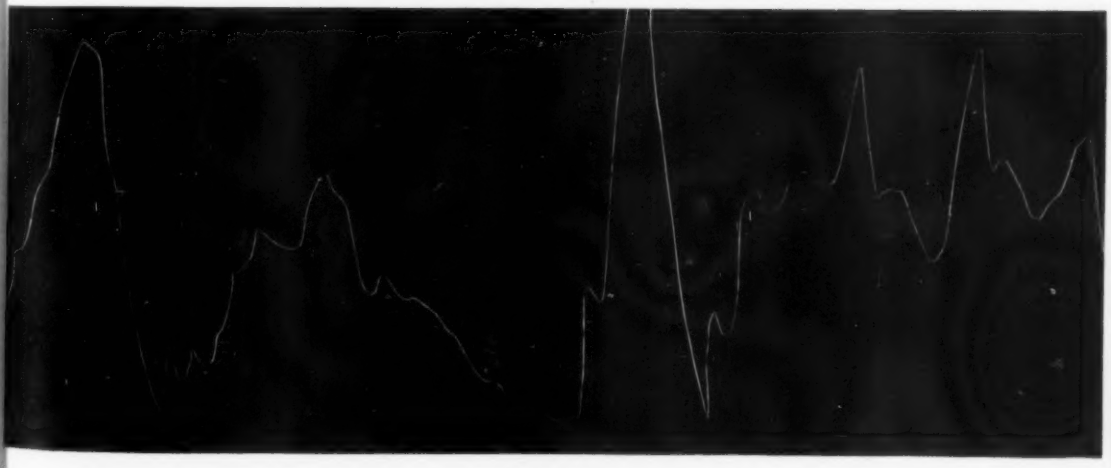


FIG. 7.
"Go tell aunt Rodie."

PLATE II.

VOLUNTARY MOVEMENT UNDER POSITIVE AND NEGATIVE INSTRUCTION

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In two previous articles[1] upon the negative instruction the main interest was directed toward the effect of such instruction upon the suppression of imagery and the muscles of the vocal organs. The work described in the present article was undertaken in order to obtain an analysis of the process of executing a skillful movement, that is, a movement requiring perfect motor control, under the conditions of positive and negative instruction.

The experiments were conducted in the Harvard laboratory in the spring of 1912 upon five subjects referred to as *A*, *B*, *C*, *D*, and *E*. They were all graduate students, with a training in experimental methods.

The instrument used was a tracing board similar to the one recommended by Whipple.[2] The subject passed the wire attached to the stylus through his coat sleeve, so that it would move freely with his arm and not interfere with its movements. He sat before a table of convenient height with the board directly in front of him.

The positive instruction given him was: "Go down the middle of the groove." That is, he was to pass the stylus down the middle of a grove between two brass sides 25 cm. long, and at the nearest end $\frac{1}{2}$ cm. and at the farthest end $\frac{1}{10}$ cm. apart. When the stylus touched the sides a telegraph sounder indicated the contact. The precautions advised by Whipple were observed.[3] Preliminary trials were made until the subject could traverse the distance in nine

[1] 'Suppression with Negative Instruction,' *Psychological Bulletin*, June, 1910, Vol. VII., pp. 200–208; and 'Suppression with Negative Instruction,' PSYCHOLOGICAL REVIEW, November, 1911, Vol. XVIII., No. 6, pp. 411–424.

[2] 'Manual of Mental and Physical Tests,' p. 120.

[3] *Idem*, p. 121.

seconds. Ten trials were then made with the right hand, with five seconds pause between each trial. The instruction was repeated after every second trial. The subject then gave his introspection, which was recorded by the experimenter. It was deemed advisable to take the introspection at the end of the series instead of after each trial in order that the subject should not be disturbed in his attitude by too long a pause. Also any effect of practice or warming up would not be lost and altogether the voluntary movement would be a more natural one. In regard to this latter point suppose the introspection were taken after every trial. And let us also suppose there is a content in the margin of attention, which the subject attempts to describe. He finds difficulty in presenting it clearly. In the next trial his full attention is given to it and the movement is no longer normal. Although this is a danger to be avoided in all introspection, it is more difficult to do so when the introspection is frequently given. The obvious disadvantage of such more or less sporadic report, *i. e.*, that some of the data of the first trial will be lost, seems to be of relatively minor importance. And, it must be remembered, it is only the report, not the introspection which is sporadic, for the latter is spread more or less equally over the entire series.[1] At first in order to avoid suggestion the subject was merely asked to describe fully his conscious state. It was only after it was evident that certain contents were present that questions were introduced to obtain a full description of these contents. After the report of the introspection was finished and a pause of five minutes allowed for rest, ten trials were made in similar manner with the left hand, and again the introspection was noted. There was in general an intermission of one week between each series. In several instances two weeks inter-

[1] G. E. Müller in his 'Zur Analyse der Gedächtnistätigkeit und des Vorstellungsverlaufes,' *Zsch. f. Psychol.*, Ergbd. 5, Leipzig, 1911, p. 135, says: "Stellt man eine Reihe von 240 Versuchen an, so wird man bei Untersuchung mancher Fragen den gleichen Einblick in das innere Verhalten der Versuchsperson gewinnen, wenn man dieselbe nur in 30 bis 40 über die Versuchsreihe verteilten Fällen zu einem Vorgangsbericht veranlässt, wie dann, wenn man das Verfahren mit jedesmal verlangtem Vorgangsberichte anwendet, ohne dabei eine gleiche Ablenkung der Vorgänge von der Natürlichkeit zu riskieren wie bei dem letzeren Verfahren."

vened. After five series had been made under the positive instruction, in the case of two subjects after four series, the negative instruction "Do as before but this time direct your attention to inhibiting the stylus from going toward the sides in going down the groove," shortened to "Do not touch the sides," was introduced and the trials conducted in all other respects as before. The two forms of instruction, positive and negative, do not necessarily imply the same action. While under the positive a straight line must be made, under the negative the stylus may zigzag so long as it goes down the groove without touching the sides. Practically, however, in consideration of the narrowness of the groove, this difference may be neglected. In both cases the attention was directed toward steadiness of movement. Only in one instance was advantage taken of the extra privilege of the negative instruction. A subject said after one negative series that by saying to himself that he could move his hand laterally so long as he did not touch the sides, he felt less constrained.

Quantitative Analysis

One of the striking features of the results is their variability for the same individual from week to week as well as

Subject *A*

Positive Instruction

Series	Right Hand			Left Hand		
	M.	Md.	M.V.[1]	M.	Md.	M.V.
1	6.8	7.0	2.7	7.8	7.6	2.4
2	9.8	10.4	2.4	4.9	4.3	2.6
3	5.7	5.9	1.4	3.8	3.6	1.4
4	6.1	6.5	2.0	5.3	5.0	1.8
av.	7.1	7.4	2.1	5.4	5.1	2.1
Negative Instruction						
5	4.7	3.8	2.7	7.1	8.8	3.0
6	7.4	8.1	3.9	9.5	8.4	4.3
7	6.9	6.9	2.0	5.6	5.5	2.4
8	7.0	6.1	1.9	6.8	7.2	3.0
9	10.0	10.3	2.6	13.4	10.5	4.4
av.	7.2	7.0	2.6	8.5	8.1	3.4

[1] The m.v. is taken from the mean, the median is quoted throughout the paper and not the mean.

SUBJECT *B*

Positive Instruction

Series	Right Hand			Left Hand		
	M.	Md.	M.V.	M.	Md.	M.V.
1	8.2	7.7	4.1	8.7	8.5	1.9
2	5.4	4.5	2.2	7.4	6.5	3.1
3	8.5	8.2	3.8	6.1	6.6	2.4
4	4.9	5.8	3.9	7.6	5.9	4.4
5	7.9	7.4	3.3	8.6	7.5	3.2
av.	7.0	6.7	3.5	7.7	7.0	3.0
			Negative Instruction			
6	5.6	4.1	3.4	3.8	2.4	2.2
7	8.6	9.2	1.4	10.6	9.1	3.5
8	9.3	9.3	1.7	9.2	9.1	1.8
9	10.6	9.2	3.9	8.3	7.7	4.2
10	8.9	9.2	.9	12.8	12.5	4.1
11	10.2	9.5	1.6	9.4	8.6	3.2
12	8.2	9.0	1.4	7.5	8.0	3.3
av.	8.8	8.5	2.0	8.8	8.2	3.2

SUBJECT *C*

Positive Instruction

Series	Right Hand			Left Hand		
	M.	Md.	M.V.	M.	Md.	M.V.
1	5.0	5.6	2.2	7.8	7.7	2.3
2	5.7	5.7	1.2	13.4	13.9	4.2
3	7.7	7.1	2.1	11.4	11.9	4.2
4	8.4	8.8	2.7	11.2	10.0	3.6
5	9.5	8.2	4.9	11.0	10.3	2.8
av.	7.3	7.4	2.6	11.0	10.8	3.4
			Negative Instruction			
6	5.9	4.6	2.9	9.9	10.2	2.7
7	9.8	10.1	2.9	9.8	8.7	4.5
8	11.5	10.9	2.3	9.9	9.7	3.0
9	8.6	9.0	3.4	14.2	15.5	4.0
10	8.2	9.0	2.7	10.0	9.3	2.0
11	8.6	9.5	1.5	10.4	10.5	1.6
12	8.6	9.5	2.5	9.8	9.5	3.1
av.	8.7	8.9	2.6	10.6	10.5	3.0

from trial to trial. For example *B* does 4.5 cm. one day followed by 8.2 cm. the next and 5.8 cm. the next. *D* does 14.9 cm. one day, 8 cm. the next and 10.6 cm. the next. *A* does 3.8 cm. followed by 8.1 cm. and 6.9 cm. and so on. The m.v.'s are in many instances large and the degree of

SUBJECT *D*

Positive Instruction

Series	Right Hand			Left Hand		
	M.	Md.	M.V.	M.	Md.	M.V.
1	13.5	14.9	6.1	14.0	15.4	4.7
2	10.1	8.0	3.9	15.7	16.4	2.8
3	11.7	10.6	4.0	11.0	10.3	4.5
4	9.6	9.0	3.3	10.8	10.3	3.5
av.	11.2	10.6	4.3	12.9	13.1	3.9
	Negative Instruction					
5	12.7	11.0	3.8	16.5	15.5	2.4
6	10.2	10.0	2.0	10.3	10.3	2.6
7	11.5	10.6	3.2	15.0	14.9	2.1
8	9.7	9.2	3.1	11.2	9.1	2.9
9	7.2	6.6	2.2	13.0	12.5	2.6
av.	10.3	9.5	2.9	13.2	12.5	2.5

SUBJECT *E*

Positive Instruction

Series	Right Hand			Left Hand		
	M.	Md.	M.V.	M.	Md.	M.V.
1	5.4	6.5	2.3	13.9	12.7	3.2
2	10.2	10.8	1.7	10.4	10.0	4.4
3	8.4	7.3	2.9	9.5	8.1	4.1
4	5.0	5.0	2.1	10.9	11.2	3.5
5	11.6	10.6	3.0	9.6	10.7	3.2
av.	8.1	8.0	2.4	10.9	10.5	3.7
	Negative Instruction					
6	12.9	12.7	3.4	13.6	13.9	3.0
7	9.4	9.2	2.3	9.7	9.7	3.1
8	8.1	8.5	2.5	14.3	14.9	3.8
9	8.9	9.5	2.4	8.5	9.0	2.1
10	10.8	9.5	4.1	11.1	9.2	4.1
11	10.0	10.3	2.6	13.4	10.6	4.4
12	10.5	9.5	3.9	10.2	9.1	3.6
av.	10.1	9.9	3.0	11.8	10.9	3.4

correlation between low averages and small m.v.'s is slight. This large variability is not confined to either hand, but generally a large m.v. for the right hand will be followed by a large m.v. for the left on the same day and the same with the small m.v.'s. It may be significant that in the case of *D*, who is the only one who does better with both hands under the negative instruction, the m.v. is also on an average

decidedly smaller for that instruction. This same relation holds in the case of *A*'s left hand under positive instruction and *E*'s right hand under positive instruction.

There are considerable individual differences as regards the effect of the different instructions. As was just mentioned, *D* is the only subject to show improvement for both hands under the negative instruction. *C* shows slight difference for the left hand and a worse average for the right. *A* is about the same for the right and almost twice as poor for the left. *B* and *E* have a worse average for both hands under this instruction. Nowhere can one find decided results of practice. Under the presupposition that the movement is more difficult under the negative instruction, it might be said that, inasmuch as the negative followed the positive, those who did worse in the negative might have shown the effects of practice if the instruction had not been changed and those who showed some improvement might have shown a still greater one.

The first average in several instances under one or the other instruction was the best or at least very low, for example in the case of *C* for both hands under the positive and for the right under negative, *E* for the right hand under positive, *B* for both hands under the negative and *A* for the right hand under negative instruction. When only one hand showed this peculiarity it was the right, that is, the first hand used, which suggests that the low average was due to greater interest in the movement.

Qualitative Analysis

The introspection on the fore-period of all the subjects will be given and analyzed and then that of the main period. Only introspection bearing on the subject of this paper will be quoted and repetitions will, as a rule, be omitted.

Fore-period

Subject A

Positive Instruction.—(1) R. h.[1] I tried to imagine there was a groove in the middle. I got a visual image of this groove. (2) L. h. There is a visual image of a line down

[1] R. h. = right hand. L. h. = left hand. The introspection has been numbered in order to facilitate reference in the following analysis. Remarks by the writer are put in parenthesis.

the center that I am to follow. (3) L. h. The idea of going down the middle is represented by the path a ball takes that I imagine I am to bat and because I am able to associate this imagery with the left hand I am able to keep the idea of the sides out of consciousness easier and longer than with the right hand. (He always batted left-handed, although he was right-handed in other things. The record with the left hand is better than that with the right.)

Negative Instruction.—(4) R. h. The idea of keeping away from the sides was not represented by visual imagery but rather by my attention wandering from side to side of the groove. I could not think of both sides at once. (5) L. h. Auditory image of instruction was present. (6) R. h. There was a visual image of the point wavering from side to side. The sides were not prominent and faded out when I began to move down the groove. (7) L. h. The instructions were entirely auditory.

Subject B

Positive Instruction.—(8) R. h. I had an auditory image 'Down the middle.' (9) L. h. I kept the instructions pretty well in mind and seemed to succeed in keeping other things out. (10) R. h. I shut everything out of consciousness but the auditory image of the instruction, which remained in the margin of consciousness. (11) R. h. I banished everything from my mind, not even retaining the instructions. I felt I could do the test. (Not as good a record.) (12) L. h. I did not start until I thought everything was out of my mind.

Negative Instruction.—(13) R. h. Auditory kinesthetic imagery of instruction. I banished all else out of consciousness. (14) L. h. It is more difficult to keep other things out with the left hand than with the right. I had to keep repeating the instruction. (15) R. h. I tried to banish everything. I did not bring up the instruction. (16) L. h. Every time I started I recalled the instruction as auditory image. There was an effort to keep the instruction in mind. (17) R. h. I tried to get my mind centered both on going down the groove and not touching the sides. (No further description was obtained.) (18) L. h. The muscular tension is not as great as in the right hand. (19) R. h. I tried to obtain an auditory image of the instruction and to banish all else.

Subject C

Positive Instruction.—(20) R. h. I had a visual image of a long line, also of the Grande Cañon. (21) L. h. There was a visual image of a continuous line.

Negative Instruction. (22) R. h. There was an image of some long passageway. The situation was exceedingly exciting and consequently pleasant. There was some great danger connected with this imagery. There was also auditory imagery of "Keep away from the sides. Go as near as you want so long as you do not touch the sides." This seemed a better instruction, as it seemed to give me more privilege. (23) L. h. There was visual imagery as before, also a vacant state of mind when I could not keep the concept. Finally I got the idea of keeping away from two rocks, from good and evil, etc. I kept switching from idea to idea. (24) R. h. I had a visual image of a tube like the Cambridge subway. The curve in the tube represented the negative not to touch the sides. At times it was represented by the idea of not touching the lamps. (25) L. h. There was a visual image of being between two rows of soldiers, who held their bayonets toward me. "Do not look to the right or left or the bayonets will stick you" was represented in auditory imagery. (26) R. h. There was sharp pain in my ear and tension in my head. The instruction was represented by the idea that my head must be kept away from something. (27) L. h. I had a visual image

of a narrow bridge. The railings were freshly painted. There was also the auditory image "Keep away from the sides" and kinesthetic sensations in the knees. (The fore-period continued to the end of the series to be occupied by a concept of some sort of danger to be avoided, although the imagery representing this idea changed from day to day.)

Subject D

Positive Instruction. (28) R. h. There was a kinesthetic sensation of a line down the center. (29) L. h. I had a visual image of a line down the middle. (30) R. h. I had the kinesthetic sensations of going down the middle. The situation was that of the difficult task of walking down the middle of a narrow plank. There was also a visual image of a central path. (31) R. h. There was a kinesthetic sensation of trying to go down a straight line. (32) R. h. I had a visual image of a straight line.

Negative Instruction.—(33) R. h. I had a visual image of walking along a plank and not going off the sides. (34) R. h. There was auditory imagery of the instruction and visual imagery of the sides and the point wobbling between them. (35) R. h. There was a visual image of a ditch and my attempt to walk down without touching the sides. There was tension accompanied by sensations of wobbling. (36) L. h. There were auditory repetitions of the instructions and vague visual imagery of the point wobbling, also tension. (37) R. h. I had kinesthetic sensations of balancing. (38) R. h. The negative part of the instruction is represented by tension of the muscles and a dizzy feeling.

Subject E

Positive Instruction.—(39) L. h. I had an auditory image of the instruction. (40) R. h. I did not say the instructions to myself until I started. (41) L. h. I said the instructions to myself. There was also a visual image of a line down the center. I did worse the times I did not say the instructions before starting. I also said "I am going to keep down the middle this time," accompanied by an effort of bracing. (8.1 cm. His best record.) (42) L. h. The instruction was not so vividly in mind. (11.2 cm.)

Negative Instruction.—(43) R. and l. h. Instructions were present as auditory imagery. (44) R. h. There was a visual image of a line, but not so far down as with the positive instruction. (45) There was the auditory imagery of the instruction and the visual imagery was not so prominent. The attention was divided between the two sides. (46) When I paid most attention to the instruction I was less conscious of the tension in the arms and vice versa.

As might be expected there was a change of imagery with a change in the instruction. A visual image of a straight line was very common under the positive instruction. In the case of one of the subjects, if this imagery did appear under the negative instruction it was in some way changed. As for example in one instance it did not extend so far, that is, it was partially inhibited (45). We also find instances under the negative instruction of the sides of the groove becoming more prominent in the visual imagery or in the perception and of the attention wandering from one side to the other instead of

remaining in the middle (35, 45, 4). Subject *C* introduced an emotional element, that of fear, under negative instruction. His visual imagery took the form of some danger to be avoided, *i. e.*, a bend in the subway, bayonets, etc.; finally the instruction centered in a rigidity of the head, which was not to be moved to the right or left. Consequently we shall see in the main period, that at times when the point touched, this emotional complex was aroused (24, 25, 26; see also 90, 96).

Subject *B*, who was the only one who had no visual imagery, occupied the fore-period in repeating the instruction verbally as much as was necessary in order to keep everything else out of consciousness (9, 10), or else tried to inhibit all thought without the aid of the instruction (16). This subject made the second best record. When, however, he worked under the negative instruction, he found it difficult to keep the instruction. Evidently the attitude suggested by the instruction conflicted with his accustomed attitude. At one point we notice he makes a compromise, in that he attempts to divide his attention between going down a straight line and keeping the idea of not touching in mind (17). His records, both with the right and the left hand, are worse under the negative instruction, although the first records made under these conditions were the best he ever made. This seems to suggest that the negative instruction increased his interest in the work at first although on the whole it hindered him.

The breaking up of an advantageous attitude used under the positive instruction by the negative instruction is clearly seen in the case of *A*. This subject does much better with the left hand under the positive instruction than with the right, although he does not usually prefer his left hand. He does, however, when using a base-ball bat, and he is therefore able when using the left hand to get very strong visual imagery and we may say a correspondingly strong muscular set by visualizing the situation on the ball field and especially the straight line taken by the pitched ball (3). The strength of this imagery also aids him in keeping the idea of the sides

out of consciousness. He is unable to place himself in a similar attitude with the right hand and hence the above-mentioned poor result. And further this imagery cannot bear for him the meaning of the negative instruction. He, therefore, avoids all visual imagery for the left hand under this instruction, merely repeating the negative instruction verbally. His records show that he is able to go only half the distance he went under the positive instruction. If we examine the introspection of the main period about to be quoted, we shall find a possible explanation for the results with the right hand. We shall see that even under the positive instruction with the right hand a more or less negative attitude was assumed. There was not so much an idea of going down the middle as of avoiding the sides. The attention was on the control of the hand to prevent it wavering. It is also difficult for him to keep the idea of the sides out of consciousness. In other words the inhibitory process was uppermost. Under the negative instruction there can, therefore, be little change of attitude. The numerical results seem to bear out this introspection, for the very slight indication of improvement in the right hand under the negative instruction can very well be due merely to practice.

MAIN PERIOD

Subject A

Positive.—(47) R. h. When I ran off to the side I had a visual image of a branch of the line which seemed to pull the point over. (48) L. h. I was not as concentrated upon the groove, because more of my attention was given to the control of my arm in order to keep my hand from going back and forth. I lose the visual image of the groove when my hand goes off to the side. (49) R. h. When the point goes to the edge I seem more conscious of the brass edge than of the central line. I try to avoid the edge. (This is a negative attitude. No further analysis was obtainable.) (50) L. h. As soon as I go off the line there is an effort to bring the hand back. The idea of drawing back the hand is somehow present. (Negative attitude again.) (51) R. h. When I get half way down I do not as a rule seem able to keep the idea of the sides out of mind. This I succeeded in doing when I made the best record. (52) L. h. I can keep in mind the path I am to follow so much easier with the left hand. (53) R. h. As I deviate from the line the idea of going down the middle leaves my mind and the sides take a prominent place in consciousness. (54) R. h. As my hand begins to waver the instructions are lost. As long as I run steadily the instructions seem well in mind. The wavering at the upper end does not seem to cause the instruction to vanish as often as the wavering at the more critical points. (55) L. h. I was not conscious of the sides. The instruction was well in mind all the way (record 0 cm.).

Negative.—(56) R. h. As the point approached one of the sides the instruction came up as an auditory image and I tried to go toward the other side. (57) L. h. The wavering of attention from one side to the other confused me to-day. (57*b*) R. h. The instruction faded out only to come up again when I approached one side or the other. Then there came the desire to push away from the side and with it a visual image of a wavy motion. (58) L. h. The same as before. Something seemed to make me go the other way when I approached the side. I believe it was an auditory image of the instruction, although it might have been a kinesthetic one. (59) R. h. It seemed as if nothing were in mind until I reached the critical point, then the recall of the instruction inhibited the movement (toward the side). (60) L. h. I had a visual image of a wavy line in the lower part of the path. When I neared the end there was a tendency to stop to get my bearings. I noticed visceral sensations when I approached the sides. They seemed to bring up the instructions. (61) R. h. The checking of the movement and the coming up of the instruction seemed to occur at the same time. There were kinesthetic sensations in the tongue. (62) R. h. I had a tickling sensation in the arm as I neared one side or the other. (63) L. h. I was less conscious of the instruction. It was more that I neglected it than that it was difficult to keep it in mind. When I approached the sides it came up again.

Subject B

Positive Instruction.—(64) R. h. There was only present the auditory image of the instruction. (65) L. h. The same as above except that when my hand began to waver my attention was directed to it. (66) R. h. I tried to banish everything else out of consciousness. For example in one instance I said to myself "No mice!" (67) L. h. My mind this morning was more on the movement. The instruction seemed to blend with the movement. (His best record with the left hand.) (68) R. h. When something came to my mind I did not make as great an effort to banish it. (Record 7.4 cm. Not as good as last time.) (69) L. h. I started my hand and let it go. The instruction was not in mind. (Slightly poorer record than the previous one.)

Negative Instruction.—(70) R. h. I watched the needle carefully and if it wavered I brought it back. (71) L. h. Even though I did not repeat the instruction it must have been in some way represented, for if the point went toward the side I immediately tried to bring it back. (72) R. h. When I made a bad record I repeated the instruction. My hand was always in a tense condition. When I went to the right or left, there was a decided effort to bring the hand back. (73) L. h. I experimented in keeping the instruction in mind and seeing if the hand would follow it of its own accord (record 9.1 cm.). It seemed easier than with the right hand to keep the instruction in mind. (Better record than with the right hand.) (74) R. h. When I struck at 20 cm. I was not successful in keeping other things out of my mind. There was a tension in the muscles of the hand. (75) L. h. It is not as difficult to keep the instruction in mind (better record). (76) R. h. The instruction was in the margin of attention all the time. When my hand moved to the side I brought it back. (That is, his attention was on that feature of the task.) (77) L. h. The instruction left more often and the movement of the hand persisted in coming into consciousness more frequently and the more it did the worse I did. (Record 12.5 cm. The worst record he ever made. The movement evidently became too prominent in consciousness, inhibiting the effect of the instruction.) (78) R. h. I noticed continually whether the point went to one side or the other. This kept other things out of consciousness. (Here he had a visual impression of the movement. In the previous series, he prob-

ably had kinesthetic imagery, which entirely inhibited the instruction as well as everything else.) (79) L. h. There was more or less tension in the hand. The other hand was clenched. When I started the instruction was only faintly in mind while the attention was centered on the point. (80) R. h. There was no difficulty in keeping other things out of consciousness this morning. I did notice tension in the muscles, however. (Record 9 cm. Only excelled by the first record of the series.)

Subject C

Positive Instruction.—(81) R. h. The idea of going out of a straight line seemed to occur before the movement. I had to renew a picture of the straight line. (82) L. h. It was more difficult to keep the image of a straight line. It kept disappearing. (83) R. h. It seemed as if the line were falling down the side of a steep embankment toward the side of the instrument. It was impossible to project the line far beyond the point. (Due to its going toward the side?) (84) When the hand went to the side the visual image of the line changed its path and came back to the straight path before the hand did. (85) L. h. When I went to the 4.5 cm. mark I had an excellent control of the visual image. (86) R. h. Only once could I keep the visual image of the straight line in consciousness. (Then he made the best record of the day, 4 cm. The average for the day was the highest of the series.) (87) L. h. It was difficult for me to carry the instruction for any length of time. My thought centered on the left hand. (Notwithstanding this difficulty he made the best record of the series with the left hand.) (88) R. h. When the point touched I experienced a mental blank. This seemed simultaneous with the touching, as far as I can say

Negative Instruction.—(89) R. h. There was present the idea of avoidance. (No further analysis was given.) (90) L. h. There was the fear of touching the sides. (91) L. h. Before I touched the side I was conscious of eye movements, combined with the auditory image "You looked." (92) R. h. There was the visual image of being in a long shaft, accompanied by great eye strain. The instruction took the form of a straight line. I could not keep the negative in mind. (93) R. h. There was a strain in the back of the neck, which became very intense as I neared the end of the groove. (94) L. h. It was quite difficult to keep the instruction in mind, quite decidedly more so than with the right hand; I noticed no tension except in one trial. (Record 15.5 cm., the worst of the series.) (95) R. h. I repeated auditorily "Do not touch those things." (96) L. h. I was frightened when I touched. (97) L. h. The image kept fading a great deal sooner toward the end with this hand than with the right.

Subject D

Positive Instruction.—(98) R. h. There was auditory kinesthetic imagery, "I must keep in the middle." My attention seemed on the point when I did best. (99) L. h. When I did well I was not thinking about it. (That trial he went to the 2 cm. mark.) (100) The first few trials I forgot the middle path and tried to keep my balance. In the last part the motor set of going down a straight line was in mind. (101) R. h. There was the kinesthetic sensations of a sweeping motion and no particular thought of the sides. Sometimes I had a visual image of the path ahead of the point. (102) L. h. When I did best there was the consciousness of a steady, even movement. The instruction was in mind as a straight even sweep. (Form of imagery not given.) (103) R. h. The instruction was not prominent. It seemed as if it disappeared just before the point touched. (104) L. h. I tried harder to keep the instruction in mind this time. The imagery was more visual. (Record 10.3.)

Negative Instruction.—(105) R. h. I found it very hard to keep the instruction in mind. In fact I tried to forget it. When I did think of the instruction I had a sensation of dizziness. When I hit I was thinking of the instruction. If I forgot the instruction I felt myself going along smoothly. (106) L. h. I thought I must keep the instruction in mind and struck sooner than when my mind wandered. (107) R. h. There was much trouble in retaining the instruction. I wanted to go down the middle instead. There was the muscular sensation of holding the stylus steady. (108) L. h. I did not repeat the instruction often to myself. There was present the auditory kinesthetic imagery "When it goes out of the middle pull it back." I had an idea that the instruction was working this time. (10.3 cm. Second best record.) (109) R. h. I was conscious of the sides and of watching the needle and pulling it back. There was tension in mouth, shoulders and arms. (110) L. h. As I saw the point approach I said "Come away from there." My mind wandered much more with this hand. (14.9 cm.) (111) R. h. I was conscious of intention to watch the point and to pull it back. There was visual and verbal imagery with some sensation of pulling the point back. The instruction tended to disappear and I kept repeating it. (112) L. h. This time I did not repeat the instruction so much. It remained in the margin of consciousness. (9.1 cm. The best record with the left hand.) (113) R. h. The instruction was dim. There was sensation of tension and a feeling of an orderly progressive movement in a straight line. Once or twice I realized I was not thinking of the instruction. When I knew I was doing well I did not try to hold the instruction. (6.6 cm. The best record with the right hand.) (114) L. h. I was more conscious of the instruction and the effort to hold it.

Subject E

Positive Instruction.—(115) R. h. When visual imagery was present I felt a much greater steadiness in my arm. If my mind wandered so did my hand. (116) R. h. There was a feeling of tension when I started down. The instruction was constantly in mind. (117) L. h. I was not able to get as definite an image of the line down the center and it was harder to keep it after I did get it. I was more conscious of kinesthetic sensations than with the right hand. (118) R. h. There was a great effort to hold the hand in the center and that broke up the visual imagery. With an effort I brought back the visual imagery. When my hand wandered it at once brought up the instruction. (119) L. h. When I touched the side I was attending to the movement rather than to the visual imagery. When I went furthest I was able to retain a distinct visual image. (120) R. h. Usually after I touched, the visual imagery disappeared. Once or twice this occurred just before I touched. I noticed a tendency to waver whenever I lost the instruction. (121) L. h. It seemed that as the auditory imagery decreased, the visual imagery increased in vividness. (122) L. h. It seems as if the instruction goes out of mind just before I touched. (He was asked to report upon this point.)

Negative Instruction.—(123) R. h. There was a visual image of the two sides. The possibility of two sides prevented a steady concentration. I went furthest when the old instruction came back to me. (124) L. h. There was a greater tendency for concentration to be inhibited. (125) R. h. I made the poorest record when I could not keep the instruction in mind. I watched the point and brought it back when it neared the side. (126) L. h. My attention was divided between the two sides. (127) L. h. I inhibited the visual image of the line as it interfered with the instruction. There was a tension in the arm. I think the time I went furthest I lost sight of the instruction. I seemed to have my eye on the side and when my hand went to the side I pulled it

back automatically. (128) L. h. Tension was very decided. The greater the tension the more successful I was. It seemed that whenever I touched the side the tension was somewhat relaxed. (129) L. h. I could note a definite correlation between tension and touching the side and vividness of instruction and touching. When the instruction faded from my mind I most often touched. (130) R. h. My arm and whole body were rigid. (131) L. h. I was not able to feel as tense. There was not a feeling of steadiness. It was slightly more difficult to keep the instruction in mind. (He made a slightly better record, however.)

Upon examining this introspection we find that there are two important characteristics of the conscious representation of the negative instruction, the inhibitory set as seen in a tension of the muscles of the hand, the back of the neck and sometimes of the whole body (72, 74, 79, 91, 93, 109, 128) and a focusing of the attention upon the movement of the stylus (70, 71, 109, 111, 127). In the latter case the verbal instruction is not infrequently either in the margin of consciousness or entirely absent as a conscious element. The repetition of the instruction in the fore-period may be sufficient to enable it to continue through the main period as a determining tendency in the form of a neural set. The perception of the movement to the right or the left, which by the force of the instruction immediately occupies the fovea of attention, induces directly an inhibitory action and the hand is drawn back.

A further difference is seen in the greater difficulty to keep in mind the verbal negative instruction (92, 105, 107, 110). It seems probable that this is due to the fact that the instruction in its verbal form, "Do not touch the sides," suggests the idea of touching or at least the idea of the sides, and as this is opposed to the purpose of the task, it is more or less suppressed by the determining tendency and instead is represented by some form of imagery which directly aids the movement and at the same time adequately represents the meaning of the instruction.

In the preliminary report of this work[1] mention was made of the fact that there were indications of a greater difficulty in keeping the instruction in mind for the left hand than for the right. That is, there seemed to be a coördination between

[1] 'The Clark Meeting of Experimental Psychologists,' *Psychological Bulletin*, June, 1912, p. 236.

the smoothness of the nervous discharge (assuming that the left hand is the unpracticed hand) and the ability to keep the corresponding imagery in consciousness. There are exceptions, as may be seen in the above introspection, when a greater ease was reported for the left hand and even as regards the movements of the right hand we have quoted an instance in which this difficulty of retaining the imagery was met with in a case where the record was a very good one. Yet on the whole the data of the completed tests bear out this preliminary statement (94, 97, 114, 124). That subject *A* was able to keep the instruction well in mind with the left hand is explained by the unique association described above, which this subject made with the left hand (52).

This brings us to a survey of the presence of imagery as an accompaniment of the voluntary act. In the case of all the subjects we find some instances of imagery, but the amount varies greatly, as does also the difficulty they have to retain the desired imagery and the importance they attach to its presence. Subjects *C* and *E* frequently call up visual imagery (85, 86, 115, 117, 119, 124, and notice it especially when the record is good as in 8). In subject *A*'s consciousness there is little representation of the instruction until the point wavers, when it appears in verbal form. His are the best results. In 54 and 55 we find exceptions. Here the instruction is in consciousness and the results good. Subject *B*, who has the second best record, has little imagery except the repetition of the instruction, which is done, partly at least, to keep distracting thoughts out of his mind. When the hand is moving smoothly and the records are good we find entire absence of the instruction (99, 112, 113).

An attempt was made to discover if the verbal instruction and other imagery disappeared just before or at the time the point touched the side. This was in many instances difficult to decide. In fact under almost any conditions the time order is one of the most difficult things upon which to introspect. That the act of touching should, through its disturbing influence drive the instruction out of mind is natural, but that the original imagery should persist until the pencil

touched, even though the hand is no longer following the instruction but going to the side, shows that there is still present a will impulse, although may be a most incipient one, directed against the actual movement (88, 120). That the imagery under the positive instruction should disappear at the moment the point began to deviate would be expected (48, 57, 81, 103, 120, 122). On the other hand the negative instrution should appear as the point begins to waver (56, 57, 58, 163).

As in the fore-period, so also here, only in the case of subject *D* do we find any reference to imagery either visual or kinesthetic of the intended movement. This was in the form of a kinesthetic sensation of a sweeping motion down the board (100, 101, 102).

Conclusions

Although the foregoing facts are gathered from only five subjects during the short period of four months they suggest the following:

1. The variations in the average of ten tests on the accuracy of movement for one individual from week to week are so great, for example 3.8 cm. one week followed by 8.1 cm. on the succeeding test day, that the results of one day cannot be taken as an index of an individual's motor control. It might be argued that, as the first tests are often the best of a series, they might well be taken as an index. There are, however, too many exceptions to justify this conclusion.

2. Just as in the reaction experiments we have two different attitudes, a motor and a sensory, producing two different sets of results, so here we have what for want of a better name may be termed a positive and a negative attitude toward the task and these attitudes also influence the results. This does not mean that the subjects at times assumed only a negative attitude. It would be absurd to suppose that the negative, not to touch the sides, could produce the movement down the board. What is meant is that a negative attitude exists along with a positive attitude either as conscious content or as neural set and that in many instances

here described the negative attitude was uppermost. We saw that at least one subject—*A*—assumed a negative attitude under a positive instruction and that the results clearly showed this. The indications are that the best work is done under the positive instruction, but this may vary in individuals, Subject *A* adopted voluntarily the negative attitude for the right hand. Whether this was the best for the neural arc of that hand or whether, if he had forced himself into a positive attitude, his results would have been better cannot be answered here. Certainly in consideration of these results the wording of the instruction becomes important. In laboratory experiments the introspection to ascertain what is the actual attitude is essential. With untrained subjects, especially with children, this is impossible. A uniform attitude can, however, be suggested by the experimenter and at least partially obtained by emphasis and explanation.

4. Except in the case of one subject, *D*, and once with *A*, neither in the fore-main or main period, under the positive or negative instruction, was there any imagery of the intended movement. Although there were considerable individual differences, the usual conscious content aside from the verbal instruction was a representation of the end or result to be obtained, especially under the positive instruction. It must be remembered that this was a movement requiring accuracy and skill. We know that under similar conditions in daily life this is the attitude assumed. The pitcher sees the ball cutting the plate, the bowler sees the line which the ball makes. In the questionary sent out by Professor Thorndike[1] the majority of the psychologists preferred the statement "To make your spear fly straight and pierce the breast of your enemy, it is useful to imagine the spear striking him full in the breast" to the following: "To make your spear fly straight and pierce the breast of your enemy, it is useful to think hard of the visual, tactile and kinesthetic sensations originally produced by the performance of the movement itself." Aside from the auditory imagery of the instruction, the visual imagery of the result best sets off the several neural

[1] 'Ideo-Motor Action,' PSYCHOLOGICAL REVIEW, March, 1913.

arcs. An act of skill requires a smooth movement, which is produced by the proper innervation of a group of muscles. If the attention were on the movement, one particular part of the movement is liable to receive undue emphasis and the desired result will not be obtained. The end result—in our work a visual image of the line to be traversed—is related by experience to each group of muscles equally and therefore best serves the purpose.

If, as according to the ideo-motor theory, an idea tends to produce the movement it resembles, then it seems more than likely that, taught by experience, it would have been an image of the movement, either visual or kinesthetic, which our subjects would have most often selected. That with the above-mentioned exceptions not one of our subjects did so, speaks against this form of the theory. This is in support of the doctrine set forth by Thorndike.[1]

5. The negative attitude was characterized in the case of all the subjects by an initial innervation of antagonistic muscles, which innervation had its conscious representation in a feeling of tension at times extending to muscles other than those to be inhibited.

6. There were subjects who required imagery, visual and kinesthetic, in order to carry out the movement. There were also those who needed only the instruction verbally and at times not even that. A repetition of the instruction in the fore-period would set off a sufficiently strong determining tendency, so that all that was necessary was to add another, a negative tendency, *i. e.*, that of keeping all else out of consciousness. Even those who required visual imagery reported that an especially good result was obtained without

[1] *Op. cit.* See also his 'Elements of Psychology,' pp. 281–284. Our data are also in accord with C. T. Burnett's as published in 'An Experimental Test of the Classical Theory of Volition. Studies in Philosophy and Psychology,' pp. 393–401. Further we find our results supporting Thorndike's statement in his 'Ideo-Motor Theory,' p. 100: "The rule is that a mere likeness does nothing; when . . . an increase in likeness goes with a decrease in the strength of the habit's bonds, likeness has the appearance of diminishing an idea's potency to arouse its act; when greater likeness of an idea to an act implies greater frequency of the idea as a situation leading to the act in past behavior, then greater likeness has the appearance of increasing the tendency of the idea to arouse that act." Compare the attitude assumed by *B* with his left hand.

the instruction being represented. Those who trusted most to a non-represented determining tendency did the best. This seems to suggest that the progress in muscular control is inversely proportional to the amount of imagery employed. In the beginning imagery is required. As the control becomes better the imagery may drop out. If the coördination is still imperfect a comparatively successful movement is only obtained when the imagery is present. As in the case of *E* there is a good correlation between relatively satisfactory movement and permanence of imagery. On the other hand there are probably those who inherit more or less perfect coördination and with such persons the imagery may disappear within a very short time. These are generally the skillful persons and they can as a rule give you the least information as to how they performed the task.

Finally the attitude of keeping all else out of consciousness is also significant. That is essential to skillful movement. A determining tendency is at once inhibited, at least partially, by the entrance of a foreign thought. This suggests a reason why a certain type of mind is unskilled in movement, that is, the imaginative type, which is continually thinking of other associated things. As there are more of the imaginative type among the intellectual, so it is not surprising that there is more motor skill among the non-intellectual.[1]

It would seem that when E. C. Rowe says that "in matters of control ideational processes are only vicarious and supplementary, and even then their functional value may be

[1] Bolton, T. L., 'The Relation of Motor Power to Intelligence,' *A. J. of Psych.*, 14, 1903, pp. 615–631. The statement of Professor J. B. Watson in his article 'Psychology and Behavior,' PSYCHOLOGICAL REVIEW, March, 1913, pp. 174, that "It has been shown that improvement in habit comes unconsciously. The first we know of it is when it is achieved, when it becomes an object. I believe that consciousness has just as little to do with thought processes" is not in contradiction to my exposition, if I interpret Watson's view correctly. The subject is probably not conscious of the improvement. It would be a fallacy to suppose that he interpreted the amount of imagery in terms of degrees of practice. This relation is found by the experimenter after an examination of the results of introspection. In the last sentence if 'to do' is meant to imply an interaction, then I should say the statement is correct. If, however, a correlation between conscious states and degrees of improvement is found, then the amount of conscious content does stand as an index of this improvement and in that sense it has 'to do' with the improvement.

questioned. Control is necessarily perceptual and sensory" he overlooks the fact that the ideational processes represent the determining tendencies and that it is only when this representation is present that we should speak of a fully conscious voluntary movement, that is, a movement in its highest stage of development, before the short-circuiting in the lower centers has begun.[1]

[1] See E. C. Rowe, 'Voluntary Movement,' *A. J. of Psych.*, 21, 1910, p. 562.

THE ASSOCIATION EXPERIMENT: INDIVIDUAL DIFFERENCES AND CORRELATIONS[1]

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This paper deals with the correlation of certain laboratory tests in association, with class standings in mathematics, science and foreign languages.

The association experiment used was by a somewhat more complete method than the ordinary free association experiment in that complete introspections were recorded.

The following 100 words were used as stimulus words:

1. arch	26. bar	51. secure
2. prude	27. president	52. giggle
3. egotism	28. fluster	53. inhuman
4. single	29. juicy	54. ecstacy
5. chastity	30. death	55. lace
6. ginger	31. press	56. hint
7. shrew	32. beauty	57. blush
8. adapt	33. retard	58. wicked
9. tough	34. ghostly	59. conscience
10. morality	35. future	60. shoulder
11. rubber	36. text	61. graft
12. coquet	37. success	62. behave
13. kick	38. abstract	63. sacrifice
14. forward	39. fatalism	64. philosophy
15. truth	40. gauze	65. trifle
16. cake	41. error	66. bedlum
17. skeptic	42. gargle	67. consent
18. extort	43. energetic	68. courage
19. modest	44. apathy	69. cowardice
20. religion	45. silk	70. course
21. knife	46. stage	71. habit
22. fanatic	47. curse	72. gamble
23. insult	48. duty	73. purity
24. flaxen	49. valor	74. drug
25. soul	50. velvet	75. snake

[1] This experiment was conducted at the University of Illinois in 1911 and the complete data, including a record of the 1,200 introspections, is to be found on file in the library of the university.

76. intention	84. temperance	92. quitter
77. caution	85. chide	93. thrill
78. alimony	86. law	94. character
79. atheism	87. virtue	95. thief
80. cuckoo	88. reverse	96. guile
81. height	89. handsome	97. bully
82. deject	90. temper	98. revel
83. concept	91. heaven	99. revenge
		100. iniquity

It will be noticed that a very generous proportion of them are more or less abstract in their nature. These abstract words were chosen with the aim of bringing out significant modes of reaction, which it was thought they would accomplish more readily than concrete and less difficult words. The remainder are intended to represent a random sampling of the words used in ordinary life.

The instructions to the observers were that upon hearing one of these stimulus words they were to react with the first word that came to mind. They were told that no logical relation between stimulus word and reaction word was demanded—the only requirement being that the reaction word must be one suggested in some manner by the stimulus word.

The time between stimulus word and reaction was measured by means of a stop watch, operated by the experimenter. The watch was read to 10ths of a second by estimation between 5ths of a second divisions and was started and stopped by the armature of an electric magnet which was in circuit with an easily operated key. This arrangement proved more precise than could be obtained by manipulating the watch directly. A series of tests to determine the probable error in the time of observation due to the experimenter's manipulation showed it to be slightly less than .1 second, *i. e.*, his average deviation in measuring a stimulus of known duration was about .1 second. The time between the end of the stimulus word and the beginning of the reaction word is taken.

After the reaction the observer was asked for a complete introspection concerning the association process and a shorthand record of this account was taken. (The entire data

for this experiment comprising some 80 closely written pages are too bulky to incorporate in this article.) The data are classified according to three schemes. (The detailed classification is likewise omitted having little significance separate from the original data.)

1. All the associations which the introspections showed referred to some particular situation are classed in a *Particular Situation* class. All other associations are put into a *General Situation* class. The reference to a particular situation is shown by the visual imagery or other thought process being a memory of some specific circumstance. The following are illustrations of this class: The association of Observer *E*, No. 5, was as follows: stimulus 'chastity,' reaction 'pure,' introspection "I thought of one of Shakespeare's plays. The class discussed the character of the play and the purity of the heroine. Visual image of the page in the book dealing with this." Another illustration: Observer *I*, No. 23—stimulus 'insult,' reaction 'offence,' introspection "The idea came from having recently heard Ex-Governor Glenn, who spoke about the insult to the white population. He seemed to pronounce the word as though it were 'insulu-it.'"

2. The data are classified according to the imagery involved, using the following seven subdivisions: *Articulatory; Visual; Kinesthetic;* a *General* group composed of Olfactory, Gustatory, Cutaneous, Auditory and Organic; *Second Articulatory* (by which is meant that the reaction word is one that had occurred at least once before in the series); *Second Visual* (by which is meant that the visual imagery is the same as that called up by some preceding word); *No Imagery.* In a very considerable number of observations, more than one kind of imagery was involved. In such cases as many different kinds of imagery were credited with the reaction as the introspection showed to be present. The reliability of these different classes differs greatly. The first class, *Articulatory Imagery*, is very unreliable for the reason that most of the observers, although advanced students of psychology, were uncertain as to the criteria of articulatory imagery. This was equally true of kinesthetic, olfactory, gustatory, cutane-

ous, auditory and organic imagery. It is not the case with visual imagery; here the introspections are definite and in only a few cases does the observer show doubt as to the existence or non-existence of visual imagery. The *Second Articulatory* class is exact, depending entirely upon the previous use of the reaction word. In explaining his introspections the observer very generally used the stimulus word and necessarily thought it in all cases. For this reason in later reactions, if the reaction word previously occurred as a stimulus word the association was classed under *Second Articulatory*. The *Second Visual* class proved so small that it need not be considered. The *No Imagery* class is a small one, comprising only those reactions in which the observer definitely denied the presence of imagery. If the introspection contains no statement at all in regard to the imagery the association is put into the Articulatory class, thus further tending to make the class unreliable. The only two classes considered accurate for the purpose of this study are the *Visual* and *Second Articulatory*.

3. A classification according to the nature of the mental process involved in association is used. It is a modification of the classification used by Wells[1] and consists of the following 15 classes: (1) Sound; (2) Phrase Completion; (3) Synonyms; (4) Contrast; (5) Coexistence; (6) Predicate and Judgment of Quality; (7) Subordination; (8) Coördination; (9) Supraordination; (10) Egocentric; (11) Egocentric Predicate; (12) Subject Relation; (13) Object Relation; (14) Causality; (15) Failure. An explanation in some detail will be necessary to indicate just what is put into each class and the lines of demarcation between the classes. The classification is a purely arbitrary one and there is no natural line of division between classes, but that fact does not in itself destroy the usefulness of the classification if it is possible to measure the degree of relation between the classes and thus utilize their interdependence. A further discussion of this point is given later in describing the method of grouping. The following principles are followed in the classification of the data:

[1] *American Journal of Psychology*, January, 1909.

1. Class 1 comprises those associations in which the sound of the word played the leading part, as in the following: Observer *D*, No. 49, stimulus 'valor,' reaction 'vanity,' introspection "A sound reaction. After reacting the meaning came as 'bravery.'" Associations in which the reaction word is some modified form of the stimulus word are also found in this class, *e. g.*, observer *D*, No. 64, stimulus 'philosophy,' reaction 'philosopher.' There is little difficulty in determining the associations which belong to this class, though occasionally an uncertainty arises, *e. g.*, stimulus 'man,' reaction 'mankind' might properly be either in this class, the class Supraordination, or the class Phrase Completion. This difficulty is not serious, as the introspections almost invariably indicate to which class such a reaction belongs. The difficulty in distinguishing between class 2 and class 1 is slightly greater than that between any of the other classes and class 1.

2. Class 2 is comprised of those reactions in which a word (in case the stimulus is the first part of a compound word), a phrase, or an idea, is completed by the addition of another word or words. Such a reaction as the following: stimulus 'text,' reaction 'text-book' is put into this class, though it does not differ much from the following: stimulus 'man,' reaction 'mankind,' which would have been put into Class 1. Another illustration of a reaction put into this class is the following: stimulus 'shrew,' reaction 'Taming of the Shrew,' introspection "I thought of the play 'Taming of the Shrew' in articulatory terms." This class is not as clearly defined as the first, conflicting more or less with most of the other classes. Illustrations of the conflict with the different classes are readily available—the following is one: stimulus 'black,' reaction 'white,' introspection "I thought of the phrase 'black and white.'" Whether this belongs here or in Contrast is a question. If the phrase were 'black and blue' it would have been put into this class. The Phrase Completion class especially competed with the Subject Relation and Object Relation classes in its claim for certain reactions, *e. g.*, observer *D*, No. 88, stimulus 'reverse,' reaction 'engine,'

introspection "Clear visual image of the throttle of an engine." This quite clearly belongs in the Object Relation class, but if the introspection had been "I thought of the phrase 'reverse the engine,'" the reaction would have belonged in the Phrase Completion class. In a number of cases the introspections do not clear up the difficulty. It is felt by the writer that the distinction between the Phrase Completion class and the Subject Relation and Object Relation classes is particularly indefinite.

3. The Synonym class is composed of those cases in which the reaction word is more or less accurately a synonym of the stimulus word. The Identity, or Synonym, class gradually grades into the Coexistence class or the Coördination class. However, if a word might equally well be put into the Coexistence or Synonym class, it was always put into the latter.

4. The Contrast class is composed of those reactions showing contrast between stimulus and reaction word, and also of certain reactions in which the introspection shows plainly that the idea of contrast is present, though the stimulus and reaction words do not show it, *e. g.*, observer *I*, No. 69, stimulus 'cowardice,' reaction 'fight,' the introspection giving as the idea, that the opposite of cowardice—courage—can be shown only by a fight. As the idea of contrast between stimulus and reaction is less and less pronounced this class grades imperceptibly into the class Coördination. It is also related to Coexistence since a large number of contrasting ideas are also coexisting. If the contrast is not a perfect one there may be a question whether the association belongs in the Contrast or one of the classes Subordination, Supraordination. This latter difficulty did not prove a very general one.

5. The Coexistence class is a very general class. It is related to all the other classes, though it was not credited with any reaction that could be put into any other one. When the reaction word is quite apparently related in some way to the stimulus word, but in so obscure a way that it cannot be said to be a relation of Identity, Contrast, etc., the association is classified here. In certain of the reactions

of this class the stimulus and reaction words represent things which coexist in nature, and in certain others the stimulus and reaction words represent two ideas which coexist only in the realm of thought.

6. In the beginning of the classification it was attempted to distinguish between a simple predicate and a judgment of quality, but the two classes so nearly approached identity in the mind of the classifier that it was abandoned and in the following discussion the two classes are grouped as a single Predicate class. There are two main types of association in this class: (*a*) those in which some object is named as the stimulus and a predicate of it given as the reaction word, and (*b*) those in which a predicate is named and some object given to which this predicate is appropriate. A reaction such as the following would be put into this class; stimulus 'beauty,' reaction 'girl.' It is thought that such a stimulus is taken either as 'beautiful' or immediately suggests it, making the association of the genuine predicate type.

7 and 9. The classes Subordination and Supraordination may be easily separated by arbitrarily saying that such a reaction as the following; stimulus 'horse,' reaction 'animal,' shall be put into the Supraordination class and a reaction; stimulus 'animal,' reaction 'horse,' shall be put into the Subordination class, and such has been the method here used, but an attempted analysis of the thought processes involved by no means yields such a clear-cut distinction. The Predicate and Subordination classes seem related since the mental process of attaching a specific example to a larger class is quite analogous to that of attaching a predicate to an object. For a similar reason the Predicate and Supraordination classes seem related.

8. The Coördination class is arbitrarily limited to cases in which the stimulus word and reaction word are of equal logical value, unless the introspection shows in some other case that the coördination idea is present, *e. g.*, it is of course quite possible that the idea of coördination may be present when stimulus and reaction words are as different as the following; stimulus 'beauty,' reaction 'man'—in such a case

the introspection might reveal that the idea was of a 'beautiful woman' and a 'handsome man.' The relation between Coördination and Synonyms, and Contrast, has been discussed under those topics.

10 and 11. The class Egocentric contains only eight observations and the class Egocentric Predicate contains none at all, hence the discussion of these classes will be omitted. It is quite possible that they might be of very considerable size with different observers.

12 and 13. The Subject Relation class is comprised of two kinds of reactions: (*a*) those in which the stimulus word is a verb and the reaction word the subject of it, and (*b*) those in which the stimulus word is a noun, conceived of as the subject of the reaction word, which is a verb. Similarly there are two kinds of reactions put into the Object Relation class. The similarity between these classes and the Phrase Completion class has already been noted. The number of observations in these two classes is small.

14. Causality is a very limited class and comprises those reactions in which the stimulus represents the cause of the reaction word, or vice versa. The following is an illustration; observer *E*, No. 23, stimulus 'insult,' reaction 'man,' introspection "Hazy visual image of a man coming along the sidewalk and shoving a lady over to one side." The illustration cited shows the close connection between this class and the Subject Relation and Object Relation classes.

15. The Failure class is composed of two kinds of reactions: (*a*) those in which there is a blocking of the association processes and a corresponding inability to react, and (*b*) those in which the reaction, though set off by the stimulus word, has no connection with it and is, in reality, a reaction to an ideational process inaugurated by the observer entirely independent of the stimulus word. Very few reactions of this nature occurred, and in fact the entire class is small.

Following is a table showing the more important elements of the complete classification.

Observers	Reaction Time	Variability	Particular Situation	Visual Imagery	Second Articulatory
A	1.38	.32	20	74	16
B	1.03	.20	43	70	6
C	1.34	.50	6	5	3
D	1.44	.89	5	33	3
E	1.71	.43	49	57	8
F	1.40	.30	9	38	9
G	1.20	.30	30	71	7
H	1.34	.30	4	41	7
I	1.44	.33	49	48	3
J	1.27	.38	6	62	13
K	1.06	.24	8	82	43
L	1.64	.35	22	56	4

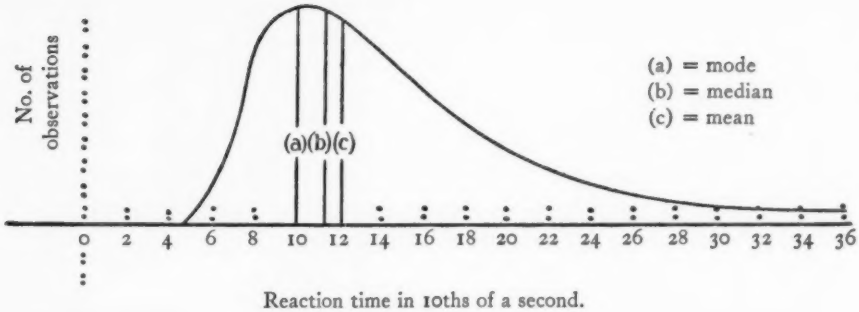
	Sound	Phrase Comp.	Synonyms	Contrast	Coex.	Pred.	Subor.	Coör.	Supra.	Egoc.	Subj. Rel.	Obj. Rel.	Causal	Failure	
A	4	9	21	2	11	36	8	4	0	4	1	0	0	0	*A*
B	2	14	4	3	14	43	5	6	6	0	1	1	1	0	*B*
C	1	15	49	0	9	14	3	0	1	0	1	0	3	4	*C*
D	36	9	19	4	5	8	3	3	2	0	0	1	0	10	*D*
E	12	8	11	2	17	24	4	5	5	0	3	5	2	2	*E*
F	2	28	25	11	11	10	1	3	1	0	2	1	4	1	*F*
G	3	8	22	1	23	18	14	0	0	0	2	3	5	1	*G*
H	3	9	28	5	12	18	5	3	1	3	3	3	4	3	*H*
I	6	6	33	13	12	5	3	8	5	0	0	3	2	4	*I*
J	2	7	31	16	5	12	2	12	1	0	1	2	4	5	*J*
K	4	12	3	1	12	30	2	2	10	0	8	9	3	4	*K*
L	7	17	14	4	12	16	4	6	5	1	5	3	5	1	*L*
	82	142	260	62	143	234	54	52	37	8	27	31	33	35	

In this table the measure of the reaction time, appearing in the second column, is the median. One half the difference between the upper and lower quartiles (the semi-quartile difference) is given as the measure of variability. In the remaining columns the figures given indicate the number of reactions put into these classes.

Reaction-Time Measures

The use of the median instead of the mean as the best measure of reaction time is based upon the fact that there is a skew distribution of reaction times, represented by a curve such as shown on the following page.

The mode and mean are on opposite sides of the median, the mode being closer to the short time reaction end and the mean closer to the long time reaction end of the distribution curve. One factor tending toward such a skew dis-



Reaction time in 10ths of a second.

tribution lies in the existence of a number of reactions in which there is a blocking or conflict in the mental process, thus excessively lengthening the reaction time. If this factor could be entirely eliminated it is still probable that there would be a skew distribution since there is an absolute lower limit, less than which the reaction time cannot be, but no such upper limit. With such a skew distribution the average is too greatly affected by a few large observations to make it a desirable measure of reaction time. Again, the mode takes no account whatsoever of any measures except those neighboring to it and is therefore not a desirable measure. The median is affected to an equal extent by every measure and is here considered the best single value to measure the reaction time of the individual. The same objection that applies to the mean applies to such measures as the average deviation, or the standard deviation, as measures of variability, and for the same reason that the median is chosen as the best measure of reaction time, the semi-quartile difference is chosen as the best measure of variability.

Grouping of Classes

In the classification according to the nature of the mental process involved there are fifteen classes, with varying numbers of observations in each. In order to have measures of the types of reaction which are more reliable than is possible under such conditions certain of these classes have been combined into groups. There are at least two methods for determining the classes which shall be so combined.

1. The combination of the classes into groups according to the judgment of the classifier, his idea as to the intimacy of the classes being the sole justification for combining them. Instead of adopting such a method, which would be simply an *a priori* judgment on the part of the classifier, the following is used:

2. The observers are ranked according to the total number of observations occurring in one class and then ranked again according to the total number occurring in a second class. With these rankings as a basis the degree to which the two classes are correlated determines whether the classes are grouped or not. In a similar manner every class was correlated with every other class. We may well assume a similarity of mental process to be involved in reacting according to the different classes so grouped. The following table shows the correlation existing between each class and certain of the other classes:

	Sound	Phrase Comp.	Synonyms	Contrast	Coex.	Predicate	Subor.	Coör.	Supra.	Causal	Subj. Rel.
Sound	1.										
Phrase Comp.	−.28	1.									
Synonyms	−.75	−.37	1.								
Contrast			.44	1.							
Coexist	.31		−.37		1.						
Predicate			−.55	−.55	.60	1.					
Subor.				−.34	.55	.55	1.				
Coör.			.09	.69				1.			
Supra.	.31		−.69		.34			.47	1.		
Causality	−.34							−.44	−.55	1.	
Subj. Rel.			−.47		.41	.55			.28	.47	1.
Obj. Rel.	.50	−.28	−.38		.57				.57	.28	.62

The method of calculating these coefficients of correlation and their probable errors, which is .19 or less, is given later. In any square in the table the coefficient of correlation found is that between the classes indicated at the top of the column and the left of the row in which the coefficient occurs. Those squares left blank indicate that the correlation is small, in fact in no case larger than one and one third times the probable error. An inspection of this table shows that certain classes may be combined into groups on the basis of high correlation between them.

(Alpha) Synonyms, Coördination and Contrast are combined into a single group, Alpha, on account of the following correlations; between Synonyms and Contrast, .44; between Contrast and Coördination, .69. The positive correlation between Synonyms and Coördination, .09, is so small as to be practically no additional reason for the grouping.

(Beta) Object Relation, Subject Relation and Causality are combined into a single group, Beta, on the basis of the following correlations; between Object Relation and Subject Relation, .62; between Subject Relation and Causality, .47; and between Causality and Object Relation, .28.

(Gamma) Predicates, Subordination and Coexistence are combined into a single group, Gamma, on the basis of the following correlations; between Predicates and Coexistence, .60; between Coexistence and Subordination, .55; and between Subordination and Predicates, .55.

The following classes are not grouped: Phrase Completion, Sound, Supraordination. Phrase Completion shows no decided positive correlations. Sound is appreciably correlated with Object Relation, but not with the subjects Causality and Subject Relation, which are highly correlated with Object Relation, and therefore Sound is not grouped with Object Relation. For a similar reason Supraordination is not grouped. Coexistence is not classed with the subjects in group Beta for it is more highly correlated with the subjects, Predicates and Subordination, with which it has been grouped.

The positive correlation coefficients here given are somewhat too small and the negative coefficients too large for the reason that there is a tendency toward negative correlation, since the more in one class the less number that remain which can be put into another class. After a reaction is put into one class there is less probability, in the ratio of 99 to 100, of any other class containing as great a number as it otherwise would. For this reason the importance of negative correlation coefficients lies in their ability to indicate which classes are most strongly opposed, rather than to accurately measure the amount of opposition.

Following is a table giving the number of times the observers reacted according to the Alpha, Beta and Gamma types:

	Alpha	Beta	Gamma
A	27	1	55
B	13	3	62
C	49	4	26
D	26	1	16
E	18	10	45
F	39	7	22
G	23	10	55
H	36	10	35
I	54	5	20
J	59	7	19
K	6	20	44
L	24	13	32

This table is obtained by combining the appropriate columns of the table on page 487.

The complete record of introspections makes it possible to investigate what effect the elaborateness of the association process has upon the reaction time. This is done in the following manner:

In addition to the three schemes of classification already mentioned the data are classified according to the number of ideas or the number of different kinds of imagery present in each association, as shown by the introspections. Each association is given a grade for its elaborateness, 1, 2, 3, etc., which is based upon the number of discrete ideas or different kinds of imagery present, *i. e.*, if the introspection shows but a single idea and but a single kind of imagery then the association is graded 1. If the introspection shows one idea, but expressed through two kinds of imagery, or two ideas, sufficiently separate from each other to warrant being called two discrete ideas, expressed through but one kind of imagery, then the grade is 2, and similarly for grades 3 or 4. The determination of the number of ideas and, to a less extent, the determination of the different kinds of imagery is only approximately possible, but only a relative determination of the elaborateness of the associations is sought and, so far as external criteria can determine this fact, the introspections and the scheme of grading adopted probably answer the

purpose fairly well. Although the associations are here put into 1 idea, 2 ideas, etc., classes, it is not to be supposed that associations naturally divide themselves into such classes and that there are not as well associations of an elaborateness corresponding to the grades $1\frac{1}{2}$, $1\frac{3}{4}$, $2\frac{1}{3}$, etc.

It is to be noted that the classification according to the number of ideas or kinds of imagery is entirely irrespective of whether these ideas or different kinds of imagery are consecutive or simultaneous. In some cases the introspections reveal a train of thought composed of three or four ideas, but more frequently they reveal simply a number of ideas and kinds of imagery, which may have been either simultaneous or in the form of a train. The possibility of having two separate simultaneous ideas is neither affirmed nor denied—the position is that the introspections, in the majority of cases, where more than one idea is present, do not reveal whether one idea has arisen after the other or whether the two or more ideas are simply different aspects of a single state of consciousness.

All the reactions are classified as indicated, after first discarding those in which the observer distinctly indicated that there had been a blocking or conflict in the thought processes. The following table gives the number of observations in each class, the median reaction time and the upper and lower quartiles.

A reference to the median values shows that there is approximately an increase of .14 second between any class and the one above it. The significance of this increase is apparent when compared with some measure of deviation, *e. g.*, the semi-quartile difference, which, from the last column in the above table, we find to be .31 second. That is, there is an increase of 14/31 of the median deviation for each additional idea or kind of imagery present in the association. Even this measure, viz., 14/31 of the median deviation, is difficult of entirely significant interpretation.

The most adequate measure to interpret linear relation is a coefficient of correlation. The data being here considered are not entirely satisfactory for correlation purposes for the

		One Idea	Two Ideas	Three or More Ideas	Total
A:	No. observations	23	39	23	85
	L. Q.	1.2	1.0	1.4	1.15
	M.	1.4	1.2	1.6	1.3
	U. Q.	1.6	1.4	2.0	1.6
B:	No. observations	33	38	14	85
	L. Q.	.9	.8	.9	.9
	M.	1.0	1.0	1.1	1.0
	U. Q.	1.0	1.1	1.25	1.15
C:	No. observations	74	13	.....	87
	L. Q.	1.0	1.35	.....	1.0
	M.	1.18	1.8	.....	1.2
	U. Q.	1.63	2.15	.....	1.7
D:	No. observations	44	28	4	76
	L. Q.	1.0	1.0	1.28	1.0
	M.	1.15	1.2	2.3	1.2
	U. Q.	1.73	1.68	3.03	1.8
E:	No. observations	23	50	20	93
	L. Q.	1.3	1.4	1.4	1.3
	M.	1.4	1.7	1.65	1.6
	U. Q.	2.0	2.08	2.28	2.1
F:	No. observations	64	28	5	97
	L. Q.	1.2	1.23	1.0	1.2
	M.	1.3	1.55	1.1	1.4
	U. Q.	1.68	1.9	1.4	1.8
G:	No. observations	69	23	6	98
	L. Q.	.8	1.1	1.15	.9
	M.	1.1	1.4	1.5	1.2
	U. Q.	1.4	1.9	1.93	1.5
H:	No. observations	44	38	10	92
	L. Q.	1.0	1.1	1.13	1.0
	M.	1.2	1.3	1.5	1.3
	U. Q.	1.4	1.5	1.78	1.5
I:	No. observations	59	28	6	93
	L. Q.	1.1	1.23	1.18	1.1
	M.	1.4	1.5	1.45	1.4
	U. Q.	1.7	1.8	1.98	1.7
J:	No. observations	61	29	4	94
	L. Q.	.9	.9	1.25	.9
	M.	1.2	1.2	1.8	1.2
	U. Q.	1.55	1.4	2.35	1.6
K:	No. observations	60	28	3	91
	L. Q.	.8	.9	.8	.8
	M.	1.0	1.0	1.0	1.0
	U. Q.	1.3	1.3	2.6	1.3
L:	No. observations	84	10	1	95
	L. Q.	1.3	1.5	.....	1.3
	M.	1.6	1.8	2.4	1.6
	U. Q.	1.9	2.15	.....	2.2
Total No. observations		638	352	95	1,086
Weighted Average Measures	L. Q.	1.03	1.10	1.21	1.04
	M.	1.25	1.35	1.52	1.29
	U. Q.	1.59	1.64	1.99	1.66

following reasons: (1) The division into classes of 1 idea, 2 ideas, etc., is too coarse a grading, for 91 per cent. of the observations are found in the first and second classes. (2) The distribution according to the number of ideas is skew, having a mode at 1 idea and tapering off to 4 or 5. (3) The distribution of the reaction times is skew, having a mode at 1.0″, a lower limit at .5″ and an upper limit at about 3.5″. (4) The 1,086 observations are not equally independent, being comprised of twelve sets of about 90 each, each set being the data for one individual.

Considering these objections in order: (1) This is an objection which cannot be overcome, but its effect will be to decrease any coefficient of correlation found, so that it will not be the cause of spurious correlation. (2) and (3) The fact that the distributions are skew does not in itself vitiate the use of a Pearson coefficient of correlation. A far more important consideration is that the relation shall be linear, which it is approximately. (4) In order to obviate this difficulty a coefficient of correlation can be calculated for each individual and the average of them will give the average correlation found. Calculation upon this basis gives the following results:

Observers	r's
A	.204
B	.413
C	.250
D	.095
E	.123
F	.043
G	.340
H	.219
I	.154
J	.137
K	.038
L	.144
Average	.180
Probable error	.020

It is thus seen that the average correlation found is .18, with a small probable error of .02.

The Observers

Before giving scholarship records a word as to the observers will be in order. The observers are all men with the exception of observer *C*. Observers *A*, *B*, *C*, *D*, *F*, *G* and *H* are either graduate students or have completed work for a Ph.D. degree. The others are all advanced undergraduates. Observer *E* is a Japanese student who has a good command of the English language. Observer *I* is a Russian and a linguist of very exceptional ability. He is gifted with a remarkable memory and is also exceptionally strong in mathematics, engineering, science and economics. Observer *H* is a keen student of philosophy and his grades in other scholastic subjects are perhaps considerably below his ability in them. This is also probably the case with some of the other observers. For reasons mentioned in the next paragraph the rankings in mathematics, science and foreign languages do not conform exactly with the grades received in these subjects; however, the rankings given are upon the basis of grades and are indicative of ability only in so far as are the grades received.

Rankings in Mathematics, Science and Foreign Languages

Mathematics, science and foreign languages were chosen because grades in these subjects are more accessible than is true of subjects less universally pursued. The grades recorded in the following table were taken from the registrar's records when possible. If the student's undergraduate work was done at some other institution equivalent grades at the University of Illinois were taken. In some cases this involved an estimate, which was based upon the student's own judgment of his ability and upon other available information in regard to equivalent grades.

Following is a table of grades and rankings. (A star indicates a change in the order of ranking from that of grading.)

	Mathematics		Science		Foreign Language	
	Grade	Rank	Grade	Rank	Grade	Rank
A	91	1*	91	4	87	6
B	81	7	88	6.5	94	2.5
C	93	3	94.2	3	94	2.5
D	88	5	95	2	84	8
E	83	6	88	6.5	89	4
F	90	4	93	1*	86.5	7
G	73	11.5	77	11	85	5*
H	73	11.5	80	10	83	9
I	84	2*	86.5	5*	98	1
J	80	9	85.7	8	69	12
K	80	9	76.5	12	72.5	11
L	80	9	82.2	9	77	10

In every case where the order of ranking has been changed from that of grading and an observer with a lower grade in a subject ranked ahead of some with higher grades, the change is amply justified because the lower grades are averages of grades received, in whole or in part, in advanced courses and the grades of the observers passed were received in more or less elementary courses. To illustrate: observer *I* with a grade of 84 in mathematics is ranked second, ahead of observers *C* and *F*, but not ahead of observer *A*. *I*'s grade is for advanced work in mathematics, as also is *A*'s, but *C*'s and *F*'s grades are for elementary mathematics. It is the opinion of the writer that the ranking given corresponds very closely with the ranking of these observers if determined according to grades received in identical courses in mathematics, science and foreign languages, but it is not thought that such grades would represent very accurately the abilities of the students in the subjects named for the reason that certain of them would make little effort to rank well according to grade. For example, *G* and *H* both receive grades around 95 in subjects which interest them and which they spend their time upon, and if *ability* in mathematics could be measured it is hardly likely that they would stand last.

Tables

The following table gives rankings in all the preceding tests. The abbreviations at the head of the table have meanings as follows: Mathematics; science; foreign lan-

guages; (the remaining measures refer to the association experiment); median time of reaction; variability in reaction time, *i. e.*, the semi-quartile difference; recall of a particular situation; visual imagery; second articulatory imagery, *i. e.*, repetition in the use of reaction words; Alpha group; Beta group; Gamma group, as defined on p. 490.

TABLE OF RANKINGS

	Scholarship			Association Test							
	Math.	Sci.	F. L.	Time	Var.	Part. Sit.	Vis.	Second Art.	Alpha	Beta	Gamma
A	1	4	6	7	6	4.5	2	2	6	11.5	2.5
B	7	6.5	2.5	1	1	3	4	8	11	10	1
C	3	3	2.5	5.5	11	9.5	12	11	3	9	8
D	5	2	8	9.5	12	11	11	11	7	11.5	12
E	6	6.5	4	12	10	1.5	6	5	10	4	4
F	4	1	7	8	4	7	10	4	4	6.5	9
G	11.5	11	5	3	4	4.5	3	6.5	9	4	2.5
H	11.5	10	9	5.5	4	12	9	6.5	5	4	6
I	2	5	1	9.5	7	1.5	8	11	2	8	10
J	9	8	12	4	9	9.5	5	3	1	6.5	11
K	9	12	11	2	2	8	1	1	12	1	5
L	9	9	10	11	8	6	7	9	8	2	7

Following is a table of coefficients of correlation, calculated from the rankings in the preceding table:

	Scholarship			Association Test						
	Math.	Sci.	F. L.	Time	Var.	Part. Sit.	Vis.	2d Art.	Alpha	Beta
Math.	1.	.....	.....	.....	.....	.....	.....	.....	.....	.....
Sci.	.81	1.	.....	.....	.....	.....	.....	.....	.....	.....
F. L.	.44	.31	1.	.....	.....	.....	.....	.....	.....	.....
Ass'n Time	−.31	−.34	.00	1.	.....	.....	.....	.....	.....	.....
Var.	−.13	−.41	−.15	.60	1.	.....	.....	.....	.....	.....
Part. Sit.	.25	.00	.60	−.18	.25	1.	.....	.....	.....	.....
Vis.	−.31	−.71	.00	.41	.50	.22	1.	.....	.....	.....
2'd Art.	−.18	−.34	−.44	.25	.50	.00	.48	1.	.....	.....
Alpha	.37	.37	.19	−.28	−.37	−.34	−.50	−.22	1.	.....
Beta	−.55	−.75	−.44	.08	.38	.00	.34	.37	−.31	1.
Gamma	−.22	.28	.22	.41	.55	.47	.65	.34	−.65	.22

In any square the coefficient of correlation given is that between the subjects indicated at the top of the column and the left of the row in which the coefficient occurs. These coefficients are comparable with Pearson coefficients of correlation, but were not calculated according to the Pearson

method. Spearman R-coefficients of correlation were calculated and transferred approximately into Pearson r-coefficients by means of the relation, $r = \sin(pi/2 \cdot R)$. The probable error of a zero coefficient of correlation is .19. ($P.E._r = 1.5$, $P.E._R = 1.5\ (.43/\sqrt{n})$.)[1] If the correlation is as high as .40 we may feel certain that there is appreciable correlation and that the probable error is less than .19, but I cannot give a formula quantitatively expressing this. The formula $(1 - r^2).19$ quite likely is not far from correct, but it lays no claim to either mathematical or empirical justification.

Interpretation and Conclusions

The small number of individuals studied necessitates that the results be constantly interpreted with reference to their probable errors. In the following work significance will be given particularly only to coefficients of correlation greater than .40, at which point the chances are about 10 to 1 that at least some correlation does exist.

Following is a restatement of the table on page 497 arranging subjects in the order of magnitude with which they are correlated with mathematics, science and foreign languages:

Mathematics		Science		Foreign Languages	
Sci.	.81	Math.	.81	Part. Sit.	.60
F. L.	.44	Alpha	.37	Math.	.44
Alpha	.37	F. L.	.31	Sci.	.31
Part. Sit.	.25	Gamma	.28	Gamma	.22
Ass'n Var.	−.13	Part. Sit.	.00	Alpha	.19
Second Art.	−.18	Second Art.	−.34	Ass'n Time	.00
Gamma	−.22	Ass'n Time	−.34	Vis.	.00
Ass'n Time	−.31	Ass'n Var.	−.41	Ass'n Var.	−.15
Vis.	−.31	Vis.	−.71	Second Art.	−.44
Beta	−.55	Beta	−.75	Beta	−.44

An inspection of these columns reveals the following facts:

1. The recall of a particular situation shows a positive correlation of .25 with mathematics and of .60 with foreign languages.

2. Reaction time and variability in reaction time are not strongly correlated with these subjects, though what correlation exists is negative and strongest with science.

[1] Whipple, 'Manual of Mental and Physical Tests,' p. 35.

3. Repetition in reaction words shows a slight negative correlation, especially with foreign languages.

4. Visual imagery is negatively correlated, especially with science.

5. The group Alpha (Synonyms, Coördination and Contrast) is favorably correlated with mathematics, science and foreign languages.

6. The Gamma group (Predicates, Coexistence and Subordination) is not materially correlated with these scholastic subjects.

7. The Beta group (Subject Relation, Object Relation and Causality) shows a pronounced negative correlation with all three subjects.

The reason for the existence of the tendencies noted is largely a matter of conjecture and the following are given as theories of explanation:

1. The recall of a particular situation is evidence of ability in a certain operation of memory. Excellence in foreign language demands a certain operation of memory. The high correlation between the recall of a particular situation and foreign languages indicates that the two operations of memory referred to are either the same or have some common factor.

2. No explanation for the small correlations found in (2) is attempted, further than to offer the theory that those able in science are rather slow but sure in their thought processes and therefore the tendency is to longer reaction times.

3. Repetition of words is considered by Jung and Riklin[1] as evidence of a limited vocabulary. Excellence in foreign language is closely connected with the possession of a large vocabulary. In explanation of the high correlation between foreign languages and the second Articulatory class (Repetitions) the theory is advanced that the mental condition in which there is difficulty in learning a foreign vocabulary is the same as, or intimately connected with, the mental condition in which the repetition of words in the association experiment occurs.

[1] *Journal für Neurologie und Psychologie*, 1903–04. Diagnostische Assoziation Studien.

4. Regarding the function of visual imagery: Some, at least, of the introspections exhibit visual imagery as a mediating factor in the association process, *i. e.*, a necessary link between stimulus and reaction; *e. g.*, observer *A*, No. 15, stimulus 'truth,' reaction 'u,' time of reaction 1.8″, introspection "Strong visual image of the word spelled out. Search for a related word finally discontinued and reaction 'u' because of its vividness in the word 'truth.' There was no attempt to prevent vocalization of the letter, since I had no thought that it would not meet the condition of the experiment which requires that the reaction shall be a word." The introspection indicates that the visual imagery mediated between stimulus and reaction. A number of such reactions occurred. However most of the visual imagery can be explained as attendant imagery, *e. g.*, observer *B*, No. 71, stimulus 'habit,' reaction 'instinct,' time of reaction 1.7″, introspection "Visual image of the natural history building, then of the physiological laboratory, then of the zoölogical laboratory at Chicago, then of an unbound copy of the *Journal of Animal Psychology*, then of an article, apparently by Yerkes, then Lloyd Morgan's book 'Habit and Instinct.'" In by far the majority of cases of visual imagery the association is less elaborate than the case just cited. The following is an illustration of a large class; stimulus 'beauty,' reaction 'girl,' introspection "I had a visual image of a beautiful girl." In such an association the belief that the visual imagery is merely attendant is less forced than in the illustration given immediately before, but there is little difference in principle between the two. If visual imagery is simply attendant to the process of association and is not in general a mediating factor then it is unnecessary and possibly a disturbing influence, and it may be that those without it spend that energy in more productive processes and therefore rank highest in scholastic work. This conclusion is in agreement with the finding of Galton that men of science are peculiarly lacking in visual imagery.

5. An analysis of certain of the fundamental conceptions of mathematics and science may reveal a reason for the

correlation of .37 between each of these subjects and the group Alpha (Synonyms, Contrast and Coördination). Such a conception as that of the surd roots of a quadratic equation involves the idea of coördination and contrast very explicitly. All conceptions involving inverse operations, *e. g.*, differentiation and integration, are definitely conceptions of contrast. Mathematical operations, such as solutions of equations, definitely involve concepts of equality or identity, which is very similar to the conception involved in the giving of synonyms. Considering the similarity of process in mathematics and in the comparison and contrasting of equivalent names, it is not surprising that there is a correlation between mathematics and the group Alpha, but rather that the correlation is not larger than is indicated in the table.

The high correlation between mathematics and science is in itself sufficient to account for most of the correlation between science and the group Alpha.

The correlation between the group Alpha and foreign languages, .19, is smaller than a consideration of the importance of synonyms in foreign language work would lead one to anticipate. A correlation coefficient, not shown in the table, between foreign languages and synonyms gives the correlation as .34.

The classification contains no group comparable to Jung's Definition class. Such a reaction as the following, stimulus 'father,' reaction 'chief of the family,' Jung[1] cites as belonging to the Definition class. His conclusions that the definition type of reaction is a simulated type and is evidence of low mentality, do not apply to the Synonym class in this experiment for the following reasons: (*a*) There would be few, if any, reactions found in the Synonym class in this experiment, which would precisely correspond to Jung's Definition class. (*b*) The postulate of simulation is a theory of explanation and not a fact of evidence. While simulation has been the subject of considerable investigation a definite criterion thereof is still lacking. There is no ground for the assumption that the reactions here classified as synonyms are simulated.

[1] 20th anniversary lectures of Clark University.

The results obtained in this experiment point to the fact that reactions with synonyms are correlated with a high type of ability in scholastic pursuits.

6. The Gamma group is composed as follows: 55 per cent. Predicates and Judgments of Quality; 33 per cent. Coexistence; and 13 per cent. Subordination. Things can coexist in a very large number of ways and, as already explained, the reactions were put into this class only when they could not satisfactorily be put into another. It follows that the reactions in this class are heterogeneous and high correlation between Coexistence and scholastic work could not be expected. The mental processes involved in naming predicates of an object are quite similar to those concerned in Subordination. The naming of predicates is neither a particularly difficult, nor a particularly simple task, but is quite colorless and on a more or less automatic level. Because of the nature of the three classes composing the group Gamma, one could anticipate only slight correlation of this group with scholastic attainments. The small correlations that the data yield are in this order: positive for science (where the importance of the naming of predicates is probably the most pronounced); positive, but smaller, for foreign languages; negative for mathematics.

7. The group Beta (Subject Relation, Object Relation, Causality) has only 8 per cent. of the total number of observations in it and is not considered as reliable as the Alpha group, with 31 per cent., or the Gamma group with 36 per cent. The description of the observations put into this group (see page 486) shows that in the mind of the classifier there is a close connection between this group and the class Phrase Completion. In other words it seems that the naming of an object when a verb is given, *e. g.*, 'hit'—'horse,' and the naming of a subject when the verb is given, *e. g.*, 'eat'—'boy,' is an association involving as little abstract thinking as a Phrase Completion association, when compared with the thought processes involved in a logical association, such as Coördination, Contrast or Synonyms. The correlation between group Beta and Phrase Completion is .15, with a probable error of .19 and if the data were more extensive a

decided correlation might be found. No great weight is placed upon the correlation found with this group, because of the known paucity of data, but nevertheless it is believed that such high negative correlations as it shows are significant of the general undesirability of the Beta group type of reaction.

8. Referring to the data upon the elaborateness of association we find a correlation of .18 ± .02 between elaborateness of association and reaction time. Though this is probably too small, it gives a quantitative statement of the relation between these two things. This coefficient establishes beyond question that reaction time is a function of elaborateness of association. (Elaborateness is to be understood as here determined.)

The entire trend of this investigation points to the fact that (1) the free association experiment yields results which are indicative of the ability of the observers; (2) that the most significant features that are favorably correlated with scholastic rank in mathematics, science and foreign languages are (*a*) capability in the recall of a particular situation, (*b*) frequency of reaction with Synonyms, Coördination and Contrast; (3) that the most significant features that are unfavorably correlated are (*a*) frequency of visual imagery, (*b*) frequency of Repetitions, (*c*) frequency of reactions with Subject Relation, Object Relation and Causality; (4) that the data, as well as a consideration of the groups, suggest that the Alpha group (Synonyms, Contrast and Coördination) method of reaction involves greater ability than the Gamma group (Predicates, Subordination and Coexistence), which is in turn superior to the Beta group (Subject Relation, Object Relation and Causality) method.

In the treatment of the association experiment the means employed for determining the relation between the classes has certain recommendations which would be of particular importance in treating more extensive data. The use of any classification, such as Jung's, Wells', or the one here used, is open to serious criticism upon the ground that actual mental processes do not follow the logical lines laid down in the classification, and therefore the justification for a logical classification must lie in some manner within itself, *i. e.*,

in its inter-class relations, as well as upon its utility after having once been adopted and used. Aside from utility the prime essential of a classification is not that it shall be logically sound, but rather that it shall be capable of exact definition. If the various classes of a classification can be so definitely defined that a second experimenter, or the same experimenter at a later time, will classify a given set of reactions in the same way then the prime requisite of a classification has been met. By the method here used the interrelation of the classes can be determined. As previously indicated, the relation between classes thus found is upon the basis of the strength of the tendency to react with a class *B* when the tendency to react with a class *A* is known. This method applied to data sufficiently extensive so that the various correlation coefficients plus or minus their respective probable errors do not overlap, would make it possible to arrange the classes in serial order upon the basis of the relationship between them; or, if this were not possible because the classes intrinsically are not related in a serial manner, it would make it possible to group the classes into such groups as they would naturally fall into and to definitely express the relation between these groups. With a classification, accurately defined as to the observations in each of the classes, and definitely determined as to the relationship between classes there is scarcely a limit to its usefulness in a large number of problems, *e. g.*, the determination of mental types, the determination of the correlation between various mental types and any other capacities that are capable of measurement (the present investigation giving a rough determination of the correlation between scholastic standing in certain subjects and certain types of association illustrates this use), the inverse problem, viz: the determination of what subjects a student is best fitted to pursue judged by the results of the association experiment, etc. A great deal of good work has been done along the lines suggested, but much remains to be done. Foremost in this is the determination of a completely satisfactory classification and it is the writer's hope that the method here used will materially help in the solution of that problem.

THE 'COLORED WORDS' OF ART

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Every artist is familiar with the fact that materials differ in plasticity as media for the expression of that particular system of esthetic ideals with which he is concerned. The wood-carver finds his hand bound by a wood of long, loose fiber, which may make it quite impossible for him to produce a given effect in his work. Line-engraving, dry-point, etching, stippling and wash-drawing have each its special field of application in pictorial reproduction. Black-and-white serves one artistic purpose, color another. The crayon and the pen give different interpretations of the same scene. Bronze and marble have such distinctive uses and canons that their employment might almost be made the basis of a differentiation in the arts. Imposed painting cannot be substituted at will for encaustic; nor is the choice ever an arbitrary one between mosaic and fret-work, relief and fresco, in architectural decoration.

A refractory material may render freedom of expression unattainable, as a narrowing tradition limits the artist's vision of the elements of beauty or cramps his conception of the means by which an ideal may legitimately be expressed. The life of the artist is a twofold striving,—first, in its endeavor toward a richer and more harmonious system of beauty, and second, toward a more plastic and expressive system of materials. The history of art also presents this dual evolution toward a fuller and more consistent conception of the scope of art itself, and at the same time toward a more highly developed and controllable material basis.

In this process the ideal element is not invariably the historical antecedent and the material its consequent. The two processes advance by alternate strides. Art waits upon the discovery of new materials and mechanical inventions,

as well as upon the appearance of creative minds and the ideal combinations to which they give birth. The existing system of materials limits the artist's expression in all forms of esthetic reconstruction, even though it be also true that at any given time unsuspected possibilities may exist in the accessible materials, to be developed by some transcendent genius. Thus the bases of the true arch, the pinnacle, the flying-buttress and the stone pendant were all latent in those very materials which the primitive builder employed for the production of his elementary effects, without any suspicion of their plastic scope. Color, mass and line made possible the indication of form as opposed to its delineation, the suggestion of motion as well as of stability, the production of an illusion of reality through the management of schemes and keys, the suffusion of neutral spaces with color and of shadows with luminosity by the massing of adjacent pigments. From the beginning, therefore, these were possibilities of the medium which cave-man and barbaric colorist employed in producing their hard lines and crude, primary effects. Nevertheless in each field of artistic expression a logical as well as practical limit exists. The medium presents an obstacle to free expression which is at last insurmountable, and determines the possibilities of ideal representation through the materials in question.

But the difference which exists among the general media of esthetic expression is not simply a question of degree of plasticity, nor even one of kind,—if by kind be meant the variety of physical materials upon which the several arts depend. Beneath these again lies a fundamental distinction, involving the nature of the ideal purposes by which the human mind is guided in its several activities, and the systems of materials, in the most general sense of the term, which it has created for the realization of these specific ideals.

It is a distinction of the second type which most commonly underlies our classification of the arts. On the basis of differences in the quality of the materials which constitute their vehicles the system of fine arts is divisible into three groups, the plastic, the literary, and the musical. The plastic arts

include all those which depend for their expression upon material substances, to be moulded into specific forms in accordance with ideal principles of selection. Their embodiments are spatial rearrangements presented to one or several senses, but chiefly to sight. This group of arts has three main subdivisions,—architecture, sculpture and painting, of which the first two belong together and the last stands by itself, not only in that the latter appeals to sight alone while the former appeal to both sight and touch, but also in that the former depend upon the same materials and constitute logically but a single art.

The literary arts include all those which depend for their expression upon verbal concepts. They are embodied in syntheses of abstract elements, the products of a logical analysis of experience, which are recombined with a view to the development of a system of ideal meanings. This group of arts includes two sub-types,—the lyric and the dramatic, which alike find their vehicle in a system of intellectual forms. The lyric is the expression of an individual and unitary attitude of the will; the drama is the expression of an interacting system of such attitudes.

The literary arts reach their highest effectiveness in poetry, but their purest form is found in prose. For this there are two reasons: the individual will-attitude is less subject to analysis than the relations of a system of connected wills, and it is therefore in greater need than the latter of reinforcement; at the same time its expression is more easily supplemented by the use of other media than the purely literary in the attainment of its characteristic effects. It thus follows that in the lyric there is less dependence upon intellectual forms than in the drama, whether the latter be cast in prose or metre. The primary vehicle, on the other hand, is supported, in the lyric more than in the drama, by what has been called the musical quality of the medium,—'colored words,' melody and sonorousness of the utterance; formal elements, such as rhythm, rhyme, verse form; and so on. In the prose forms of literary art there is much greater, though not complete, reliance upon the process of intellectual analysis of

experience and its representation through a system of logical concepts.

The musical arts comprise all those forms which include within their means of expression the compounding of pure, qualitatively varied sound. They present two great groups, vocal and instrumental music. Of these, the former attains the highest effectiveness in its impression upon the listener, while the latter possesses the purer form. In instrumental music the medium is homogeneous. Variations in sound, qualitative and intensive, and their combinations, simultaneous and successive, constitute the materials of the art, without admixture of other elements. In vocal music this whole series of factors is made use of, but there is also added the substance of the most appealing form of literary art, in the system of meanings which characterizes the song, and in the elements of rhyme, metrical form and so forth, which are carried over from poetry. The intensity of the effect is thus increased, while the medium ceases to be pure.

Of these three groups of arts the musical alone approaches the possession of a pure artistic medium. In the plastic and literary forms alike the materials upon which expression rests have had an origin foreign to the purposes of art and therefore imperfectly adapted to its ends. The materials upon which the plastic arts depend represent the system of utility, while those upon which the literary arts rest represent the system of knowledge. Man works out his practical purposes through a transformation of the material substances of the world. He has invented combinations serviceable to himself and reshaped the world's materials in such a way as to embody these ideal forms. The product of this activity is represented both in the system of manufactured objects in the mechanical arts, and in the whole series of modifications in the earth's surface which man has introduced in the course of his history.

This series of products expresses human aspirations and values in an indirect way only. They do not represent emotion and appreciation in their immediacy, but the relations among material things which man uses. Each finds its

meaning in some feature of use or control, of security or utilitarian advantage,—in a word, in the modification of this system of plastic materials which its invention makes possible. From its very nature this system of material objects is unfitted to express with freedom the activity of creative art; for it can never be stripped completely of its original associations, and through the new forms imparted to it in the course of esthetic reconstruction its native shapes peep forth,—as the personal idiosyncrasies of a poor actor break through the mask of his characterization and confuse its lines. Plastic art is compelled to express itself through a system of fixed, inert objects primarily conceived and determined by a utilitarian motive. Except, perhaps, in the case of ideal painting, this original purpose in the service of which the materials were first developed and shaped, has not been displaced and can scarcely be said to have been subordinated to that of the plastic artist. The object is a dwelling-place, a tomb, a seat, a garment, a utensil. The artist may mould the lines and color the surfaces of these objects, but he must not destroy their essential structural features or dissipate their function in thus treating column, or architrave, or lintel. Plastic art thus appears as a corollary to the primary thesis, the force of which must not be impaired in securing its effects. In the disposition of lines, masses and specific forms we are in the habit of recognizing this limitation, and our pure esthetic judgment is modified by saying, in effect: "How beautiful a natural object or a thing of use may be made!"

The freedom of movement in plastic art is thus necessarily impeded and limited by the character of its medium. When the artist seeks to transcend this limitation and to use his materials freely in the production of a purely esthetic impression, he finds his effort fruitless; for his art loses its significance in proportion as it relinquishes hold upon the specific forms of natural objects and human inventions. The limitation cannot be overcome because it is intrinsic to the medium itself. In becoming purely decorative plastic art lapses into mere convention, and in becoming singly impressionistic it is in danger of losing all universal appeal.

In short, the materials on which this group of arts is dependent do not afford an adequate means of approach to that analysis of human emotion and valuation which is essential to perfection in an esthetic medium. It is true that in the field of art universally the process in which esthetic judgment and appreciation consist is necessarily replaced by an objective product of some specific type, which fulfils the artistic purpose only to the degree in which it is capable of becoming the starting-point and support of a like activity in the beholder. But in the plastic arts, to a much greater degree than in the literary or musical, the product of expression is inarticulate. Its effect is thus rendered uncertain both in direction and in occurrence itself; for the absence of an esthetic content specifically defined will confuse the mind of the recipient and provoke it to find refuge in the only stable and obvious features which are presented, namely the descriptive and historical aspects of the forms and objects which are introduced.

In the literary arts the vehicle consists in the general system of verbal concepts which has been devised in the process of analyzing and describing the field of experience. These concepts constitute a realm of intellectual forms which represent the world's objectivity,—that is, which have been devised for the purpose of describing phenomena. It is the very purpose of this system of concepts to abstract from the attitude of the individual self for whom the objects of experience immediately exist, and to construe them in terms of their impersonal and objective relations.

Language, in which the products of this activity are embodied, is a system of descriptive concepts the very nature of which renders it inadequate as a vehicle for artistic expression. In this it resembles the medium in which the plastic arts work. Its defect, however, does not root in inarticulateness or the lack of a means of analysis, but in the character of the guiding conceptions which underlie its activities. Language represents a process in which the world is conceived as a problem for the understanding, and a logical reconstruction of its phenomena is undertaken. Within the

esthetic consciousness this logical reconstruction has no essential place, as the system of utilitarian and natural forms has no place in the appreciation of plastic art. The synthesis of materials, in both cases alike, is determined by a principle independent of the logical or descriptive point of view. The object of esthetic appreciation, like all objects of valuation, is unapproachable by the historic method. The fullest description of a beautiful object leaves its esthetic worth still untouched.

The system of verbal concepts which language represents, devised as it is for the purpose of communication and record, finds its function in description, the ideal development of which appears in the system of sciences and their theoretical aims. These represent the reduction of the content of experience in terms of objective phenomena and impersonal law. They have their roots in the logical conceptions of classification and explanation, and are embodied in a system of general terms and causal laws. Valuation and judgments of worth find no place in the purview of science, from which every personal attitude and canon of interpretation is rigorously excluded.

To fulfil the artist's purpose this system of concepts must be turned in a new direction and put to a novel use, a process which involves a revolution in the methods according to which language is employed. The artist who expresses human emotion and appreciation in literary forms is thus, like the plastic artist, dealing with an adventitious material, and is compelled to seek the realization of his purpose by a series of secondary modifications in virtue of which the difficulties imposed by his refractive medium are either obviated or transcended.

Each element employed in literary art, it may be said, each word and intellectual form, carries the mind of the reader in the wrong direction and primitively tends to arouse a form of reaction the dominance of which means a necessary inhibition of the esthetic attitude. To accomplish his aim the literary artist must therefore give a new value to every term which he employs, and make the verbal con-

cepts stand for a system of attitudes of the will instead of a system of impersonal objects. He must shake the terms of human speech free from their specific logical contents and attach to them a series of emotional reactions.

To this end the verbal craftsman has many devices. It is the pressure of this demand which leads to the differentiation of the terminologies of prose and poetry, or, more properly, of descriptive and appreciative writing. A new significance can be more readily attached to novel terms than to familiar; since the latter tend too directly and inevitably to arouse the logical-descriptive content customarily associated with them. The analysis of those peculiarly poetic words which have prose analogues does not reveal a new descriptive content, nor should it be expected to do so. These terms are not logically differentiable, because it is not a new distinction of meaning which is aimed at in the substitution, but the suggestion of a wholly different attitude on the part of the subject to whom the utterance is addressed.

There is a system of words which, in this true sense of the term, are purely poetic, the use of which is to arouse and maintain, to clarify and direct the attitude of esthetic interpretation in the recipient. It is essential to the artist's purpose that the habitual reaction of the mind to verbal concepts shall be broken up, as the initial step in his procedure. In the attainment of this end it must therefore be acknowledged that any device, consonant with the canons of his own art, is legitimate, whatever the judgment which may be passed upon its employment by the logical apprehension. Through a misunderstanding of the aim of poetry common sense may thus condemn as affectation what is an indispensable part of the method of art.

There are many ways of approaching this problem. The use of unusual or poetic words, already mentioned, is one method of attaining this end; the employment of words in unusual senses is another, which has the same effect of loosening the term's habitual connections in the web of logical thought and rendering the mind more plastic to the esthetic suggestion which it is designed to convey. One of

the most effective of such devices is the translation of terms to new orders of sense or imagination.

These artifices stimulate the mind, and at the same time baffle its efforts to give a specific content of meaning to the utterance. Mental expectancy is vivified while its logical procedure is inhibited, the consequence of which is that it is rendered more receptive of the pure qualitative effect of the stimulus. The musical values of the elements and their synthetic forms are detached and intensified, while the words themselves take on a certain absolute and mystical value which is, in itself, a positive esthetic quantity.

This mode of treatment is directed to the larger relations of the literary artist's materials as well as to its elements. It is exemplified in the use of metaphor, whereby the predisposition of the mind is at once justified and rendered incapable of definite reaction. The simile is felt but not understood; it is apprehended as harmonious with the expectations of the mind, but its specific application cannot be clearly represented in the imagination. This double effect upon the mind, of stimulation and arrest, is more violent in the usage, common in poetry, of transferring terms from their original sense-fields to other and disparate systems of phenomena, of uniting the concepts of discontinuous fields, and of joining formally contradictory concepts in a single context.

All this must of course be limited by the constitution of the recipient's mind. The procedure is instrumental; its aim is to arouse an attitude different from that of logical conception but still positive and specific in character. If it succeed only in inhibiting the original cognitive reaction without substituting an alternative activity, or in disappointing it while the effort to interpret the expression in terms of the logical understanding persists, the artist simply fails in his endeavor. The mind of the recipient must not be arrested by the fact of apparent contradiction or ineptitude in such a way as to occupy itself with the logical relations of the figure which has been employed. The artist cannot permit an essential contradiction to be formulated in the

consciousness to which his appeal is made, but only a contradiction of such degree that the mind is stimulated and rendered at the same time plastic to the impression which he seeks to convey. Fundamental harmony with the subject's predispositions at large is the basis upon which the artist's success depends. To provoke that attitude of acceptance is, indeed, not in itself sufficient; but within the system of relations which it represents the artist's specific activity must confine itself, since to abolish this sense of harmony arouses an attitude of will which is incompatible with esthetic appreciation.

The whole system of formal values which differentiates poetry from prose has the same general significance in the mechanism of expression. The musical quality of the sentence itself, rhythm in the succession of words or syllables, rhyme and other elements of metric structure,—all these have the effect of detaching the form and quality of the utterance from its meaning, of reducing the significance of the thought from its position of preëminence, and of giving a positive, if not paramount, value to the formal and qualitative aspects of the expression. The mind, instead of passing directly to the content of meaning, is arrested by the utterance, to which a positive and substantial value is thereby given. In this case the process of logical conception is not first aroused and then baffled, as it is, for example, by a misused term or by looseness of construction in prose—but the direction of the mind's activity is turned away altogether from the attempt to reconstruct continuously a logically significant utterance and centered upon another and specifically esthetic object.

The repetition of the stimulus is another form which this procedure of the literary artist takes. The recurrence of qualitative resemblance in the constituent sounds of a verse, the use of alliteration, the employment of a refrain, the repetition of even a single word in continuous iteration, have all this esthetic effect. To render any common word unfamiliar, to empty it of its ordinary content of meaning, it is necessary only to repeat it in isolation; and the poet takes frequent advantage of this fact in the production of his artistic effects.

The terms of human speech, as they ordinarily appear in context, have a value which is solely transitive; to dwell upon the word is to transform its meaning, if not to deprive it of all content. In the employment of language by the literary artist, in such cases as have been cited, there is substituted for this function of the word in originating a system of significant, or logical, associates a value which resides in the fact that this system of associates is cut off, and the word itself becomes the material center of the mind's attitude. It takes on a resident and absolute value, or at least one which is symbolical and latent. It is felt as the potential center of a system of meanings, no one of which is developed or defined. To create this nimbus of luminous but undefined suggestion is a large part of the poet's aim in his use of words.

All this machinery—which is much more extensive than has here been indicated—has been created by the literary artist in his purely preliminary function of overcoming the habitual reactions of the mind to the system of materials which he employs, since, as has been stated, the occurrence of this original reaction of logical apprehension inhibits the attitude which the poet seeks to call forth. Throughout his field the literary artist is confronted by this initial difficulty, which is due to the fact that he expresses himself through a system of verbal concepts primarily designed to serve a radically different purpose from that which he has in view.

Within the field of music the same composite material appears wherever the pure sound qualities are mediated, as in song, by a system of verbal forms which at the same time possess meaning. In singing, however, this duality is less important than in poetry, and is in large part negligible; since the modifications of utterance which musical notation introduces practically destroy the meaning which the poem is intended to convey. Even when sung in one's own language one does not seek primarily to follow the words of a song, but attends instead to the musical variations of expression; and one is scarcely incommoded by the fact that songs are often sung in a foreign tongue and cannot, in the logical sense of the term, be understood at all.

The musical arts, however, attain to a pure, or homogeneous, medium only in the case of instrumental compositions, from which the whole verbal basis has finally been eliminated, so that no logical meaning, in the strict sense, attaches to the succession of symbols employed. The vehicle, in instrumental music, is the compounding of pure sound itself, uncomplicated by conceptual content and unconditioned by a material objective basis. Art here makes its nearest approach to the achievement of a pure esthetic medium in attaining its purpose by the direct expression of human emotion freed from the presence of any other factor.

WHIPPLE'S 'RANGE OF INFORMATION TEST'[1]

BY LAURA LETTIE SMITH

The University of Texas

The question of intelligence tests of various types and for various purposes is of steadily recurring interest. The writer of this note felt it might be of value to obtain a series of percentages, based on the test outlined by Professor Whipple in this journal,[2] that might possibly indicate the comparative standing of students in a southern university. The results given here, therefore, present nothing new in method. In the final comparison, they conform quite closely to former results, though computed from a larger number of cases.

In place of the high school student, we have substituted data obtained from a group of college students. Professor Whipple did not place a time limit on the test. The conditions under which the test was given here made this necessary; approximately thirty minutes was allowed each student in which to write out the test. This proved too short for the completion of the definitions. Other steps on the procedure conform as closely as possible to the description given in Professor Whipple's article. For the list of words and cautions observed, the reader is referred to the paper just cited. The data were obtained during the winter term of the academic year, 1911–12.

TABLE I

DEPENDENCE OF RANGE OF INFORMATION ON AGE AND SCHOOL STATUS

Academic Status	Number	*D*	*E*	*F*	*N*
Graduates	9	38.11	12.11	15.67	34.11
Seniors	47	24.9	16.7	19.3	39.1
Juniors	59	20.5	14.4	20.7	44.4
Sophomores	85	20.1	12.1	19.1	48.7
Freshmen	153	13.7	10.7	15.5	60.1

[1] The writer wishes to acknowledge the assistance of Professor Yoakum in the preparation of this note.

[2] 'A Range of Information Test,' PSYCH. REV., 16, September, 1909, 347–351.

TABLE II

DEPENDENCE OF RANGE OF INFORMATION ON SEX, CLASS BY CLASS

Academic Status	Sex	Number	*D*	*E*	*F*	*N*
Seniors.....	Men	21	29.3	16.1	17.3	37.3
	Women	24	22.1	17	20.3	40.6
Juniors.....	Men	30	23.4	16	16.8	43.8
	Women	29	17.4	13.6	25	45
Sophomores.....	Men	37	24	13	17	46
	Women	48	17	11.3	20.5	51.2
Freshmen.....	Men	74	16	10.4	14.3	59.3
	Women	72	10.9	13.4	16.3	59.4

TABLE III

DEPENDENCE OF RANGE OF INFORMATION ON SEX, WITHOUT REGARD TO CLASS STANDING

	Number	*D*	*E*	*F*	*N*
Men.....	162	21	12.7	15.6	50.7
Women.....	173	15.2	13.2	19.3	52.3

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